FINAL
INTERIM FEASIBILITY REPORT
AND
INTEGRATED ENVIRONMENTAL ASSESSMENT

US Army Corps
of Engineers
Fort Worth District

PECAN BAYOU WATERSHED

BROWNWOOD, TEXAS

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Prepared by

U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300

INTERIM FEASIBILITY REPORT
AND
INTEGRATED ENVIRONMENTAL ASSESSMENT

Responsible Agencies: The responsible lead agency is the U.S. Army Corps of Engineers, Fort Worth District.

Abstract: This document focuses on the portion of Willis Creek, which flows through the city of Brownwood, Texas. The purpose of this study is to determine the most economically and environmentally feasible plan to meet the water and related land resource problems within the study area. This document addresses the economic and environmental feasibility of the investigated alternatives and recommendations. A structural grasslined, trapezoidal channel, with associated environmental mitigation measures, was found to be the best alternative for the study area, and is the Recommended Plan for this portion of Willis Creek.

Contact: If you require further information on this document, contact:

Mr. Thomas Vogt
CESWF-PM-C
U.S. Army Corps of Engineers, Fort Worth
P.O. Box 17300
Fort Worth, Texas 6102-0300

Telephone: 817-886-1378

Note: This report includes an integrated environmental assessment (EA) within the report text. Paragraphs required for compliance with the National Environmental Policy Act (NEPA) are noted by an asterisk (*) in the Table of Contents.

SYLLABUS

This document presents the results of the plan formulation process leading to the identification of a recommended plan for local flood damage reduction in Brownwood, Texas. The investigation into water resource problems and opportunities within the Pecan Bayou watershed, including the city of Brownwood, began with the Pecan Bayou Lake, Colorado River Basin, Texas, Reconnaissance Report, completed in March 1994. The report concluded that Pecan Bayou Lake, an authorized Federal project, was no longer economically feasibility, but there was a Federal interest in conducting additional detailed studies for flood damage reduction along Pecan Bayou and Willis Creek in Brownwood. With the support of the city, a cost-shared feasibility study was initiated in January 1995.

Various alternatives, both structural and non-structural, were investigated to reduce flood damages along Pecan Bayou and Willis Creek. The initial conclusion of these investigations indicated that channel improvements provided the most cost-effective means for reducing flood damages. Non-structural alternatives were investigated but have offered a minimal positive benefit-to-cost ratio (BCR) and/or had extremely minimal net benefits to economically justify through the 1 percent (100-year) flood event. Therefore, non-structural alternatives were eliminated from further study.

The analysis of a grass lined channel and swale configurations on Pecan Bayou with 10-, 50-, and 100-foot bottom widths all revealed negative net benefits and benefit-to-cost ratios of 0.36, 0.24, and 0.19 respectively. Therefore, an economically feasible alternative could not be identified along Pecan Bayou and no further detailed investigations were conducted. Channel modification investigations on Willis Creek with 10-, 25-, 45-, and 60-foot bottom widths, however, offered significantly higher net benefit results and positive benefit-to-cost ratios with the 45-foot bottom width being the optimum channel modification alternative. Further refinement of this alternative, to include a diversion channel, optimized the 45-foot bottom width with a diversion channel as the Recommended Plan, as well as the National Economic Development (NED) Plan, with expected net benefits of $313,600 with a positive BCR of 1.55 to 1.0.

The National Economic Development (NED) Plan identified in this investigation would consist of 15,680 feet of channelization of Willis Creek within the city of Brownwood. The improvement would consist of modifying the existing channel into a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal with a bottom width of 40 feet with pilot channel. The channel depth would vary between 4 and 11 feet deep with the top varying between 40 to 135 feet wide. A diversion channel will be constructed approximately 1200 feet downstream of 14th Street Bridge to the 4th Street Bridge. The improvement would also require box culvert modifications to the 14th Street Bridge and 4th Street Bridge, side slope modifications at Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection. Environmental mitigation measures in the form of avoidance would consist of bypassing several oxbows and allowing them to continue to serve as wildlife habitat and wetlands. Additionally, approximately 102.1 acres of reforestation would be undertaken to replace the habitat removed by the channel excavation.

The overall flood damage reduction plan would have estimated first costs of $8,270,190 and annual project costs of $574,000. The resultant BCR is 1.55 to 1.0 with net benefits estimated at $313,600. This plan would reduce expected annual damages by 92 percent; eliminate all damages caused by the 10 percent ACE event and would reduce nearly 90 percent of the damages caused by the 1-percent event.

The final array of alternatives formulated by the Fort Worth District has been evaluated in accordance with required Federal evaluation procedures. These include procedures from the "Principles and Guidelines", the National Environmental Policy Act (NEPA), and other Federal environmental review and consultation requirements. Consideration has been given to all significant aspects in the overall public interest including engineering feasibility and economics, social, and environmental effects to provide the best solution for meeting the objectives of the Pecan Bayou watershed area and supported by the city of Brownwood.

LIST OF ACRYONYMS

AAHU	Average Annual Habitat Units
ASA(CW)	Assistant Secretary of the Army (Civil Works)
ACE	Annual Chance Exceedance
BCR	Benefit-to-Cost Ratio
EA	Environmental Assessment
FEMA	Federal Emergency Management Agency
FONSI	Finding of No Significant Impact
HQUACE	Headquarters, United States Army Corps of Engineers
HTRW	Hazardous, Toxic, and Radiological Waste
LPP	Locally Preferred Plan
NED	National Economic Development Plan
NEPA	National Environmental Protection Agency
SWD	Southwestern Division (U.S. Army Corps of Engineers)
TNRCC	Texas Natural Resource Conservation Commission
USFWS	United States Fish and Wildlife Service
WRDA	Water Resources Development Act

Flood Event Category Nomenclature

Classic Terminology	*Current Terminology*
1-Year Flood	<100 Percent Annual Chance Exceedence Flood
2-Year Flood	50 Percent Annual Chance Exceedence Flood
5-Year Flood	20 Percent Annual Chance Exceedence Flood
10-Year Flood	10 Percent Annual Chance Exceedence Flood
25-Year Flood	4 Percent Annual Chance Exceedence Flood
50-Year Flood	2 Percent Annual Chance Exceedence Flood
100-Year Flood	1 Percent Annual Chance Exceedence Flood
500-Year Flood	0.2 Percent Annual Chance Exceedence Flood

PECAN BAYOU WATERSHED, TEXAS
WILLIS CREEK, BROWNWOOD
FORT WORTH DISTRICT
STUDY TEAM MEMBERS

TEAM MEMBER	SPECIALTY	SIGNATURE	DATE
Thomas Vogt	Project Management	Thomas R. Vogt	18 July 01
Jason Foltyn	Planning	Jason Foltyn	17 July 01
Hank Jarboe	Environmental Resources		19 July 01
Craig Loftin	Hydrology and Hydraulics	Craig H. Loftin	
Lanora Wright	Economics	Lanora Wright	
Blake Bryant	Real Estate		18 Jul 01
Larry Mendoza	Civil Design	Larry Mendoza	18 JUL 01
William Sanner	Structural Design	William O. Sanner	
Ken McCleskey	Geotechnical Design	Ken McCleskey	
Jay Newman	Cultural Resources	Jay R. Newman	
Wayne Elliott	HTRW Resources	Wayne Elliott	7.17.01
Jim Sears	Cost Estimating	Jim Sears	

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DISTRICT QUALITY CONTROL CERTIFICATION
STATEMENT OF TECHNICAL AND LEGAL REVIEW

COMPLETETION OF INDEPENDENT TECHNICAL REVIEW

The District has completed the Feasibility Phase Analysis for investigating the purposes of providing flood damage reduction, ecosystem restoration, watershed management, and more effective water management within the Pecan Bayou watershed, Brownwood, Texas. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principals and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analysis; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy. Personnel from the Fort Worth District accomplished the independent technical review.

Reviewer

William Fickel
Chief – Planning, Environmental, and Planning Division

Larry Rogers
Chief – Engineering & Construction Division

Hyla Head
Chief – Real Estate Division

Rex Crosswhite – Deputy District Council

Jerry McCrory
Chief – Civil Works, Program and Project Management

Marty Hathorn
Assistant Division Chief – Planning, Environmental, and Planning Division

Rebecca Griffith
Planning Branch Chief – Planning, Environmental, and Planning Division

DISTRICT QUALITY CONTROL CERTIFICATION
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Reviewer	**Branch/Section Chief**	**Signature**	**Date**
Les Perrin	Assistant Chief – Design Branch	Jimmy D. Boggett	7/23/01
Mead Sams	Section Chief - Economics		7/20/01
Darrel Cullens	Section Chief - Civil Design	Darrel Cullens	7/19/01
Bobby Camp	Section Chief - Real Estate	Bobby J. Camp	23 July 01
William Wallace	Section Chief - Structural	William A. Wallace	
John Wise	Section Chief - Geotechnical	John R Wise	19 JUL 01
Steve Smith	Section Chief – HTRW	Steven Smith	7/20/01
Lee Osborne	Section Chief - Cost Estimating	Otto L Osborne	
Elston Eckhardt	Acting Section Chief – Planning	Elston D Eckhardt	

STUDY AUTHORITY

The study was conducted under authority of a Pecan Bayou watershed plan authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. This Act directed "*That the following works of improvement of rivers and harbors and other waterways for navigation, flood control, and other purposes are hereby adopted and authorized to be prosecuted under the direction of the Secretary of the Army and supervision of the Chief of Engineers, in accordance with the plans and subject to the conditions recommended by the Chief of Engineers in the respective reports hereinafter designated. .... PECAN BAYOU, TEXAS .... The project for flood protection on Pecan Bayou, Texas, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Numbered 350, Ninetieth Congress, at an estimated cost of $24,861,000.*"

The authorized Pecan Bayou watershed plan contained three units: Pecan Bayou Channel Improvement, Lake Brownwood Modification, and Pecan Bayou Reservoir. The Pecan Bayou Channel Improvement was subsequently de-authorized by House Document 97-59 in June 1981; the Lake Brownwood Modification was de-authorized on November 17, 1986 by the Water Resources Development Act of 1986 (PL 99-662).

In accordance with Federal regulations, Congressionally authorized (General Investigations) water resource studies, are performed in two phases, the reconnaissance and feasibility phases. The purpose of the reconnaissance phase, conducted at a full Federal expense, is to determine if there is a Federal interest in conducting additional detailed studies, determining the scope and cost of the additional studies, and identifying a non-Federal sponsor to participate in the additional studies. Based on the above authority, a reconnaissance study was completed in March 1994. The report determined that Pecan Bayou Reservoir was no longer economically feasible and recommended additional detailed studies for flood damage reduction within the city of Brownwood. Subsequently, a cost-shared feasibility study (shared equally between the Government and the city of Brownwood) was initiated in January 1995.

STUDY PURPOSE

The purpose of this ongoing feasibility study is to investigate water resource problems, needs, and opportunities within the Pecan Bayou watershed, particularly the reduction of flood damages within the city of Brownwood. The feasibility study expands on the preliminary analyses conducted during the reconnaissance study by collecting additional data and completing detailed engineering and technical analyses. The intent is to better define the flood problem, evaluate a wide range of alternatives for flood damage reduction and select from those alternatives which are technically and economically feasible, environmentally acceptable, and supported by the city of Brownwood and the Federal Government, one alternative designated as the recommended plan.

STUDY PARTICIPANTS

This feasibility study was undertaken as a joint effort between the Fort Worth District, U.S. Army Corps of Engineers and the city of Brownwood. Coordination has been maintained throughout the study with interested Federal, state, regional, and local government officials, the news media, and citizens in the Pecan Bayou Watershed, mainly the City of Brownwood. Existing floodplain information, used in previous Federal Emergency Management Agency studies of cities and counties within the Pecan Bayou Watershed, is aiding these efforts. The U.S. Fish and Wildlife Service was consulted in accordance with the Fish and Wildlife Coordination Act of 1958 (Public Law 85-624), and have provided a Planning Aid Letter analyzing the fish and wildlife problems and needs within the Pecan Bayou Watershed. The Texas State Historic Preservation Officer was also contacted at the onset of this study. The State Department of Highways and Public Transportation provided bridge profiles and other pertinent information. The Texas Water Development Board provided 50% of the local cost share in the form of an State Flood Protection Planning Study grant to the City of Brownwood, and provided study oversight and contract management assistance during the course of the study. The United States Department of Agriculture, Natural Resource Conservation Service was contacted and aerial photographs of the study area were purchased. Additionally, local real estate companies provided land sale information for the study area.

BASIN AND WATERSHED DESCRIPTION

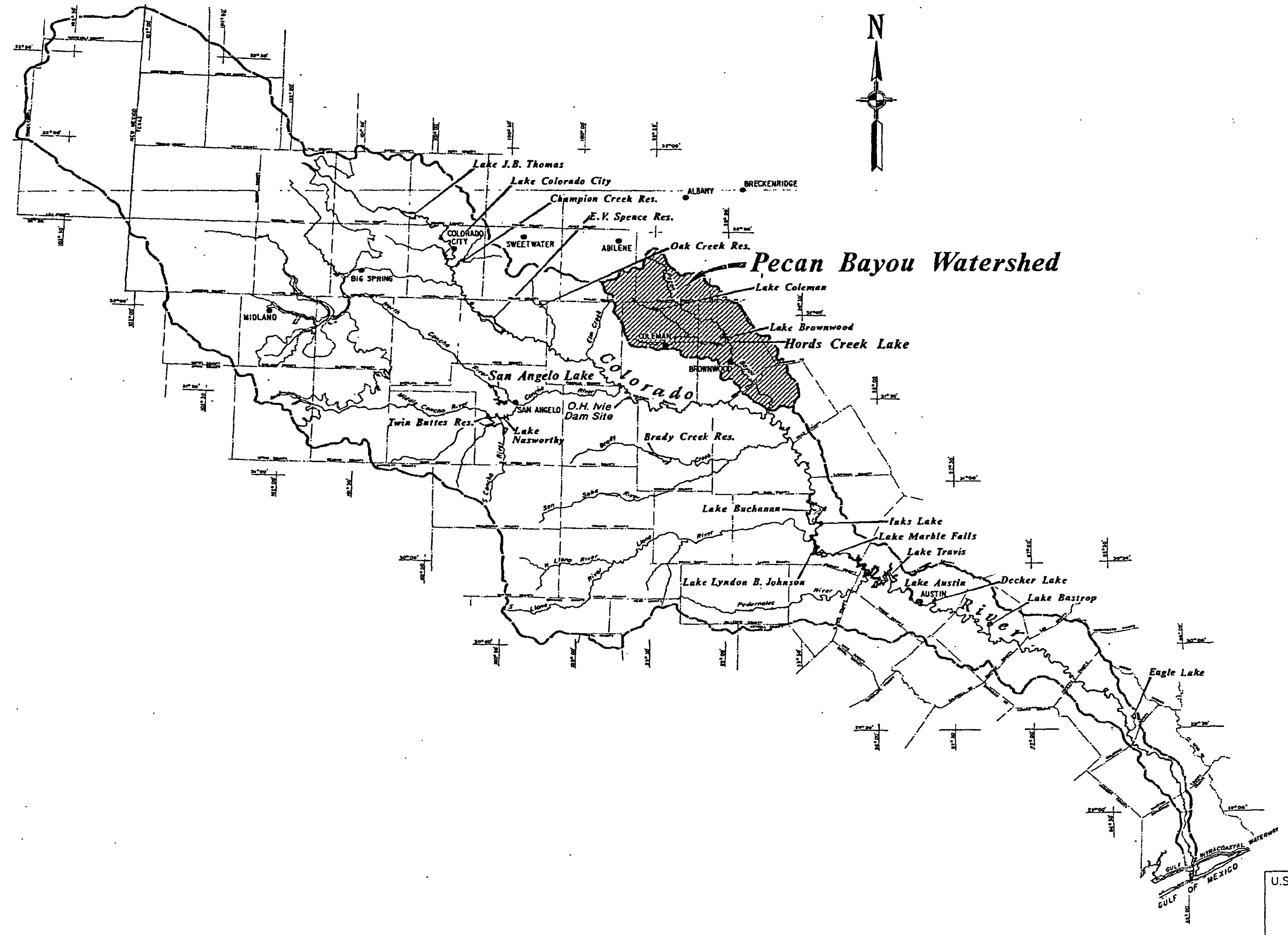
The Colorado River basin extends from the Lea-Chevez County line in the southeast portion of New Mexico some 600 miles southeasterly across the state of Texas to the Gulf of Mexico near Matagorda, Texas. The basin is bordered to the east and north by the San Bernard and Brazos River basins. The Pecos, Nueces, Guadalupe, and Lavaca River basins border the basin on the west and south. It is about 85 miles wide in the extreme upper portion, increasing to about 170 miles wide near Milburn, Texas. It then decreases to a width of about 30 miles at Austin, Texas, and maintains this width to Columbus. Below Columbus, the watershed width diminishes as the river approaches the Gulf of Mexico. The basin has a total area of 42,344 square miles with the upper portion of the basin lying in the Great Plains. This portion is a flat-semiarid region with numerous closed basins, of which 12,667 square miles do not contribute to the Colorado River drainage. The Colorado River Basin and the location of the Pecan Bayou watershed are shown on Figure 1.

The Pecan Bayou watershed is located in the north-central portion of the Colorado River Basin, near the geographical center of Texas. It is bounded on the north and east by the respective watersheds of the Clear Fork and Leon River tributaries of the Brazos River, and on the west and south by watersheds of small tributaries of the Colorado River. This pear-shaped watershed has an overall length of about 85 miles, a maximum width of about 40 miles, and an average width of about 26 miles. The watershed comprises portions of Taylor, Callahan, Eastland, Runnels, Coleman, Brown, Comanche, and Mills Counties. Major sub-watersheds include the North Prong, Hog Creek, Jim Ned Creek, Salt Creek, Willis Creek, Steppes Creek, Lewis Creek, Dudle Creek, Devils River, MacKinally Creek, Pecan Creek, Long Branch, Fish Creek, Rough Creek, and Blanket Creek. The total Pecan Bayou drainage area is approximately 2,200 square miles. Elevations within the Pecan Bayou watershed range from 2,370 feet (National Geodetic Vertical Datum) at the headwaters of Jim Ned Creek, to 1,150 feet at the confluence with the Colorado River. This is a total drop of 1,220 feet over 154 miles. A map of the Pecan Bayou watershed is shown in Figure 2.

EXISTING FEDERAL WATER RESOURCE PROJECTS

In 1943, the Department of the Army constructed a local flood damage reduction project along Willis and South Willis Creek in Brownwood to mitigate for the adverse hydraulic impacts brought about by the Camp Bowie. The project was constructed in accordance with recommendations made by the Corps of Engineers in the "Supplemental Report on Floods in Willis Creek Valley below Camp Bowie, Texas", dated March 1, 1943. The project consisted of a hydraulic channel improvement on Willis Creek from its confluence with South Willis Creek, upstream a distance of approximately 4,700 feet, a new bridge over South Willis Creek at Fourth Street, and raising and lengthening the existing bridge over Willis Creek at Austin Avenue. In addition, low levees were constructed using spoil material obtained from the channel excavation. The levees were located along the left bank of South Willis Creek from a point about 300 feet above the confluence with Willis Creek to Stephen F. Austin Boulevard, and along the right bank of Willis Creek and South Willis Creek from Austin Avenue to near Third Street. Finally, the abandoned portions of the creek channels were backfilled; several locations of the channel bank were raised to the design water surface elevation, also using the spoil material obtained from the channel excavation.

Hords Creek Reservoir, authorized by the Flood Control Acts of August 18, 1941 and December 22, 1944, is an existing Corps of Engineers project constructed for purposes of flood control, water supply, and recreation. Construction was initiated in January 1947 and the dam was placed in service on June 16, 1948. The Hords Creek Dam is located about 13 stream miles west of Coleman, Texas, and is an earth-filled embankment, which is 6,800 feet long, including an uncontrolled 500-foot-wide broad crested spillway, and water-supply appurtenances consisting of an approach channel, intake structure, and a 24-inch water line through the dam. The reservoir has a water surface area of about 510 acres at top of water conservation pool. Total capacity is of 49,290 acre-feet at maximum design water surface, of which 2,860 acre-feet was allocated to sediment storage, 5,780 acre-feet to water conservation storage, 16,670 acre-feet to flood control storage, and 23,980 acre-feet to surcharge storage.

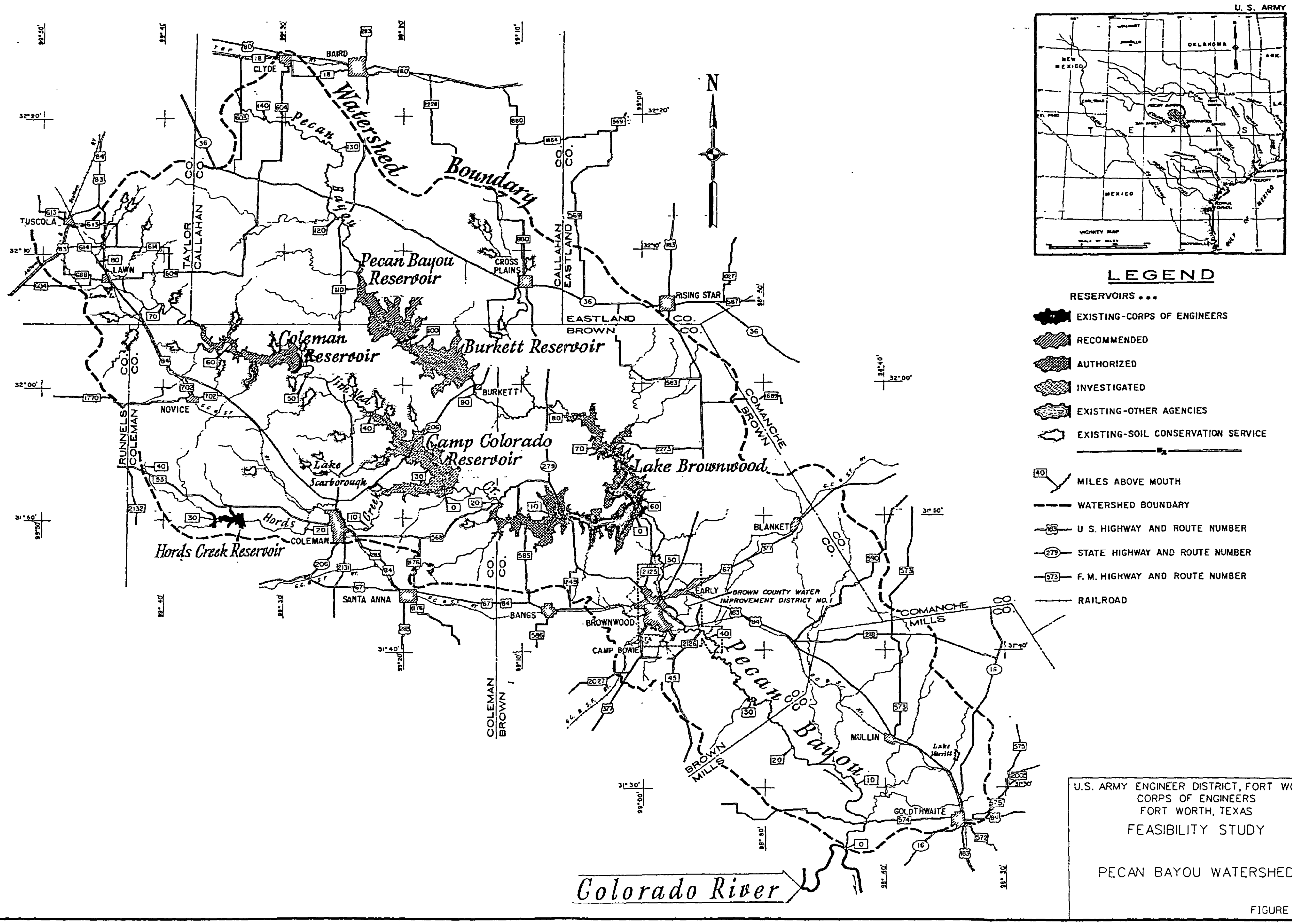


U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

FEASIBILITY STUDY

COLORADO RIVER BASIN

FIGURE 1



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

FEASIBILITY STUDY

PECAN BAYOU WATERSHED

FIGURE 2

The U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) has an ongoing flood-detention-reservoir program on the Pecan Bayou watershed. The program is outlined in the Report of the U. S. Study Commission - Texas, dated March 1962, and includes 146 floodwater retarding structures, of which 88 reservoirs are located upstream of Lake Brownwood and 58 downstream. Associated with this program the NRCS has prepared definite work plans for construction of 55 additional reservoirs upstream from Lake Brownwood.

Pecan Bayou Lake was authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. The project would provide flood damage reduction, water supply, and recreation. The authorized project consists of an earth filled dam 15,500 feet in length (including the spillway), a top width of 20 feet, and a maximum height of 107 feet. The spillway was broad-crested and uncontrolled. In 1978, the Brown County Water Improvement District Number 1 (BCWID#1), requested the Corps of Engineers to initiate Phase I Advance Engineering and Design Studies, on the Pecan Bayou Lake. However, the studies were not funded and no further contact was made until 1984 when the BCWID#1 was notified of the possible deauthorization of the project. The BCWID#1 passed a resolution on 9 July 1985, again requesting the Corps of Engineers to initiate Phase I Advance Engineering and Design Study on Pecan Bayou Lake. Again, the studies were not funded. In a 1994 Reconnaissance Study, it was determined that the Pecan Lake Bayou project was no longer economically feasible, although the project remains authorized for construction.

The Pecan Bayou Channel Improvement, Brownwood, was also authorized by the Flood Control Act of 1968 (Public Law 90-483), approved 13 August 1968. The authorized project consisted of 7.3 miles of channel improvement, having a bottom width of 300 feet, and a depth of 32 feet. Local interests did not wish to further participate in the development of this project. Subsequently, the project was de-authorized by House Document 97-59, dated 9 June 1981.

The Lake Brownwood Modification project was also authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. The project consisted of extending the existing embankment (Lake Brownwood was constructed in 1932 by local interests), lengthening the existing concrete spillway, and modifying the existing outlet structures. The detailed design was initiated and several Design Memoranda were published in 1976. However, in 1976, the Corps of Engineers determined that the project was a local dam safety issue and not a flood control project of Federal interest. The BCWID#1 constructed the modification in 1981 substantially in accordance with the Design Memoranda mentioned above. Subsequently, the Lake Brownwood Modification project was de-authorized by Public Law 99-662, dated 17 November 1986.

EXISTING NON-FEDERAL WATER RESOURCE PROJECTS

Lake Brownwood is impounded by a dam on Pecan Bayou, a short distance below the confluence of Pecan Bayou and Jim Ned Creek. The drainage area above the dam is about 1,544 square miles. The original dam was completed in 1932. Lake Brownwood provides municipal and agricultural water supply, flood damage reduction, and recreational opportunities and is operated by the BCWID#1. The dam is an earth-fill embankment about 1,580 feet long. Its maximum height is about 140 feet and it has a crown width of 12 feet. The embankment includes: two 42-inch conduits through the base of the dam near the center for drawing down the reservoir during emergencies, and a conduit near the south end of the dam for releasing water into the supply system. An uncontrolled spillway is located in a saddle about 2,000 feet north of the dam and consists of a cut through the saddle. The spillway has a width of about 479 feet. The total storage below the conservation level is about 119,000 acre-feet. The BCWID#1 has had to make major repairs on the conduits and conduit-gate structure and does not now utilize the existing Broome gates at the intake ends of the 9-foot conduits. Instead, BCWID uses the 24-inch outlets, which bypass the Broome gates, for regulating the lake level. The reduction in discharging capacity of the outlet results in more frequent use of the existing spillway.

The principal purpose of Lake Brownwood is water supply in providing water for the cities of Brownwood, Bangs, Santa Anna, and Early for municipal and industrial purposes and water supply for irrigating about 5,000 acres of arable land within the boundaries of the District. The BCWID#1 comprises about 14,000 acres of land within its boundaries, including the urban area of the city of Brownwood. In addition to serving about 5,000 acres of arable land within the District boundaries, the District, at times, sells water to irrigate portions of about 1,500 acres outside the District boundaries.

Lake Coleman is located on Jim Ned Creek and was constructed by the city of Coleman for municipal and industrial water supply. Construction was initiated in August 1965, completed in April 1966, and put into operation in May 1966. The storage capacity at the time of construction was 40,000 acre-feet. Lake Coleman, which is served by a drainage area of about 305 square miles, provides the majority of the water supply for the city of Coleman. Lake Coleman has a normal water surface area of about 2,000 acres.

Lake Clyde is located on North Prong Pecan Bayou, a tributary of Pecan Bayou, about 6 miles southeast of the city of Clyde. The reservoir was designed for municipal water supply and floodwater detention. Construction of the dam was initiated in June 1969 and completed in November 1969. The storage capacity at time of construction was 5,750 acre-feet. Lake Clyde is the primary source of water supply for the city of Clyde.

Lake Scarborough is located on Indian Creek, a tributary of Jim Ned Creek, about 4 miles north of the city of Coleman. The reservoir, completed in 1927, was constructed by the city of Coleman for municipal water supply. The storage capacity at time of construction was 2,000 acre-feet. The water from Lake Scarborough is filtered, and then delivered to Coleman through a 10-inch pipeline. Lake Scarborough, which is served by a drainage area of about 12 square miles, provides a negligible amount of water supply, and proved to be inadequate for the water supply needs of the Coleman area. Thus, the city of Coleman acquired the water supply storage rights in the Hords Creek Reservoir project prior to its construction.

PREVIOUS WATER RESOURCE STUDIES AND REPORTS

PREVIOUS CORPS WATER RESOURCE STUDIES AND REPORTS

There are numerous technical reports published that document water resources investigations made within the Pecan Bayou watershed. The following paragraphs describe, in chronological order, prior Corps of Engineers studies and reports within the Pecan Bayou watershed.

1. **Report From the Chief of Engineers on Preliminary Examination of Colorado River, Texas, with a View to the Control of its Floods, April 3, 1930 (House Document No. 361, 71st Congress, 2nd Session).** This report was a preliminary examination of the Colorado River for flood control as authorized by the acts of May 21, 1924 and February 12, 1929. This report investigated various dams and potential dam sites; however, it recommended that due to the lack of existing or prospective navigation on the river that there was no Federal interest in flood control. Additionally, the potential Federal interest in flood control was investigated and determined that the state should be responsible for all flood control activities.

2. **Report on Survey of Pecan Bayou, Texas, for Flood Control and Allied Purposes, March 1939 (House Document No. 370, 76th Congress, 1st Session).** This report recommended a plan of improvement that included the construction of Hords Creek Lake on Hords Creek above the city of Coleman and enlargement of the existing Lake Brownwood on Pecan Bayou. Construction of Hords Creek Lake and enlargement of Lake Brownwood were authorized by the Flood Control Acts of 18 August 1941 and 22 December 1944. The Hords Creek Lake project was constructed and became operational during April 1948.

3. **Definite Project Report on Hords Creek Reservoir, Hords Creek near Coleman, Texas, Colorado River Basin, February 1946.** This report presents the definite project plan for Hords Creek Reservoir on Hords Creek near Coleman, Texas, authorized by the Flood Control Act, approved August 18, 1942 (Public Law 228, Seventy-seventh Congress, first session). The project plan detailed the construction of a multiple purpose dam and reservoir, principally for flood control and water conservation. The estimated first cost was $1,479,000 with an annual operation and maintenance cost of $11,000.

4. **Review of Reports - 1948 (Unofficial).** Subsequent to the 1939 Report on Survey, a second rep*ort

entitled "Review of Reports on Pecan Bayou, Texas, Flood Protection, Brownwood, Texas," dated 3 September 1948, was prepared. This report suggested a restudy of the authorized Lake Brownwood enlargement, along with studies of alternate reservoir and channel improvement plans. This report was submitted to the Office of the Chief of Engineers and the Board for Rivers and Harbors, but was returned to the district for further revision in 1954.

5. **The Master Plan for Recreation and Land Use, Hords Creek Dam and Reservoir, near Coleman, Texas, May 1950.** This report recommends recreational facilities to be constructed at the project to accommodate the large numbers of visitors to the lake and adjacent lands. These proposed facilities were to be located on Government owned lands. Additionally, this report requested that authority for the development of these recreational facilities be approved at an early date.

6. **Review of Reports on Pecan Bayou Watershed, Colorado River Basin, Texas - October 1963.** This report investigated flooding problems along Pecan Bayou, Willis Creek, Adams Branch, and Lake Brownwood. The report recommends improvements to the Lake Brownwood and surrounding creeks, and construction of two upstream reservoirs. The channel improvements had a first cost of $11,281,000. The improvements to Lake Brownwood consisted of enlarging both the dam and reservoir at a first cost of $3,060,000. The upstream reservoirs were recommended to be multi-purpose and designated as Pecan Bayou and Coleman. The first cost of the reservoirs was $22,410,000. Neither of these projects has been constructed.

7. **House Document Number 350, 90th Congress, 2nd Session, July 8, 1968, Pecan Bayou, Texas.** This house document and subsequent act (Public Law 90-483, August 13, 1968) authorized a study in Pecan Bayou, Texas. Subsequent to the completion of the Pecan Bayou Watershed Report, a letter from the Texas Water Development Board (dated August 12, 1966) indicated that local interests had constructed a dam and reservoir on Jim Ned Creek in the general location of the proposed Coleman reservoir. Additionally, the Soil Conservation Service (letter dated April 24, 1967) was working on detailed planning for a watershed work plan (Brownwood Laterals) for Willis Creek and Adams Branch in the city of Brownwood. Therefore, these portions of the watershed plan were deleted from the requested authorization. The authorized plan of improvement included the Lake Brownwood modification, the construction of Pecan Bayou reservoir, and/or Pecan Bayou channel improvements.

8. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase I - Plan Formulation, April 1975.** This report recommended construction of the Lake Brownwood modifications. This modification would ensure the continued existence of Lake Brownwood for needed flood control, water supply, and recreation in the Pecan Bayou watershed. The plan included construction of a new dam, immediately downstream of the existing Lake Brownwood dam, and erosion control measures to prevent erosion of the existing spillway. The first cost of this project was estimated to be $21,295,000.

9. **Revised Plan of Study, Feasibility Report for Water Resources Development, Colorado River and Tributaries, Texas, Colorado River Basin, Texas, June 1975.** This report presented an amended plan of study to update the Revised Plan of Survey for Comprehensive Survey Report of the Colorado River and Tributaries, Texas, dated August 1963.

10. **Navigability Study, Colorado River, Tributaries and Lakes, Colorado River Basin, Texas (River Mile 290.1 to 890.0), February 1975.** This report determined that as of 10 February 1975, the Colorado River from river mile 291.6 to 890.0, Texas Highland Lakes and other lakes above river mile 290.1 and all tributaries of the Colorado River above river mile 290.1, together with lakes thereon, are non-navigable. This report also recommended that this portion of the Colorado River (river mile 290.1 to 890.0), Texas Highland Lakes and other lakes above river mile 290.1 and all tributaries of the Colorado River above river mile 290.1, together with lakes thereon, be declared non-navigable waters.

11. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase II - Project Design, June 1976.** This report finalized the design of the Lake Brownwood modifications. This modification would ensure the continued existence of Lake Brownwood for needed flood control, water supply, and recreation in the Pecan Bayou watershed. The plan was changed to an "add-on" or composite embankment rather than a new dam immediately downstream of the existing Lake Brownwood dam. The erosion control measures for the existing spillway were finalized. The first cost of this project was estimated to be $24,850,400.

12. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 4, Availability of Construction Materials, June 1976.** This report presents the authoritative information and the results of investigations and study regarding the availability and economics of satisfactory sources of major construction materials required for construction of Lake Brownwood modification and its appurtenant structures.

13. **Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 5, Real Estate - Lands For Construction Area, July 1976.** This report presents the location, general description, land utilization, acquisition criteria, and schedule of acquisition encompassing approximately 399 acres of the construction area. The proposed real property acquisition line considers requirements for construction of the project and the comparable sales, trends of values, relocation assistance and estimated costs for acquisition of the land and interests.

14. **A Final Supplement to the Final Environmental Impact Statement, Lake Brownwood Modification, Pecan Bayou Watershed, Colorado River Basin, Texas - March 1977.** This supplement to the EIS determined that the project would have some degradation of the water quality immediately downstream, due to construction activities. There would be a loss of wildlife habitat within the construction area, and a loss of 383 acres of cropland, which would be used as fill material for the embankment. Nine identified archeological and historic sites would be avoided during the construction.

15. **Status Report - Colorado River Basin, Texas - September 1987.** This report presents the results of preliminary investigations to identify water resource problems and needs in the basin. This work was accomplished under authority of the Colorado River Basin, Texas, basin wide authority.

16. **The Texas Statewide Inventory of Flood Protection Needs - May 1990.** This study was completed to provide an up-to-date, community-specific inventory of flooding problems and solutions for 756 cities and towns in Texas that could be incorporated into the revised state water plan. This inventory contains data from previous planning studies and National Flood Insurance Program (NFIP).

17. **Report on Flooding, April - May 1990.** This report provides a summary of the flood damages experienced and effectiveness of U.S. Army Corps of Engineers projects during the period of April-May 1990. This report contains general information on the storms and their resultant impacts. The report contains a brief description of the rainfall and various river basins that experienced flood inundation, flood losses sustained in the respective counties and cities, and estimates of damages prevented by existing Corps of Engineers projects.

18. **Reconnaissance Report – Pecan Bayou Lake, Colorado River Basin, Texas – March 1994.** This report documented a significant need for flood protection within the Pecan Bayou watershed study area, particularly within the city of Brownwood along Pecan Bayou and Willis Creek. Seven preliminary alternatives were investigated including three different detention structures, three hydraulic channel improvements, and a non-structural alternative (permanent evacuation). Two economically viable flood damage reduction plans were identified and recommended for further study. This document is the result of that study recommendation.

PREVIOUS NON-CORPS STUDIES AND REPORTS

There are numerous other technical reports published by other Federal, state, regional, and local entities that document water resources investigations made within the Pecan Bayou watershed. The following paragraphs briefly describe these studies and reports.

1. **Federal Emergency Management Agency (FEMA).** FEMA is responsible for the administration of the National Flood Insurance Program. A few cities and counties within the Pecan Bayou watershed are participants in the program. The results of the studies are shown in the flood insurance rate maps (FIRMs) published by FEMA. The following is a list of known Flood Insurance Studies completed (effective program date) within the Pecan Bayou watershed. Town of Blanket (April 2, 1992), City of Brownwood (July 6, 1982), City of Clyde (May 25, 1978), City of Coleman (April 1, 1981), Town of Cross Plains (Not in Program), City of Early (July 1, 1987), Town of Mullin (Not in Program), City of Novice (Not in Program), Brown County (March 1, 1991), Callahan County (Not in Program), Coleman County (Not in Program), Comanche County (June 20, 1990), Eastland County (Not in Program), Runnels County (Not in Program), Mills County (April 28, 1992), Taylor County (June 1, 1987).

2. **The Report of the U.S. Study Commission - Texas, The Eight Basins, March 1962.** An act of Congress, approved 28 August 1958, established the United States Study Commission on the Nueces, Trinity, Brazos, Colorado, Guadalupe, San Antonio, Nueces, and San Jacinto River Basins and intervening areas within the state of Texas. The directive instructed the Commission to make an integrated and cooperative investigation, study, and survey in connection with and in promotion of the conservation, utilization, and development of the land and water resources. The purpose is to formulate a comprehensive development plan for submission to and consideration by the President and the Congress. The report evaluated the water conservation requirements and means of satisfying them to the year 2010. However, due to the use of generalized procedures and criteria or the total lack of economic analysis of certain multiple purposes, the plan did not adequately evaluate flood control, navigation, hurricane protection, and pollution abatement. The plan was a well-conceived framework from which the ultimate objectives of comprehensive and integrated water and land resource development could be obtained. It is considered a flexible base subject to refinement and revision as prevailing conditions dictate and as more detailed analyses are made.

3. **Department of the Interior, Reservoir Operation in Texas - June 1985.** This report, authorized by the Water Resource Development Act of 1978 (PL 95-467), compiled a comprehensive listing of the water resources and their uses within the various river basins in the state of Texas. This report summarizes the reservoirs, their storage, and operating plans.

4. **Department of Water Resources, Texas, Water For Texas - November 1984.** A two-volume report was prepared. Volume 1, A Comprehensive Plan for the Future, of the amended 1969 Texas Water Plan is an executive summary that sets forth planned actions and policy recommendations. Volume 2, Technical Appendix, is a technical document which provides details of current water development and use, projected future water supply and treatment needs, and potentially developable water supplies to meet future water needs in each river and coastal basin of the state.

5. **Texas Water Development Board, Occurrence and Quality of Ground Water in Brown County Report Number 46, May 1967.** This report was prepared in response to a directive from the Texas Water Pollution Control Board and evaluated the ground water in Brown County to determine what, if any, pollution was occurring. This was accomplished by collecting and compiling information regarding the occurrence and chemical quality of the ground water used by landowners and others. Additionally, this study identified and delineated the underground formations containing useable water.

6. **Texas Water Development Board, The Texas Water Plan, November 1968.** This report outlines a flexible guide for the orderly development, conservation, and wise management of the State's water resources to meet the needs of the state to the year 2020. The plan suggests the possibility of importing large quantities of surplus water from the lower reaches of the Mississippi River to areas of greatest need in Texas.

7. **Texas Water Development Board, Water For Texas, Today and Tomorrow, December 1990.** This report updates and presents the 50-year plan for the state of Texas, including the current and prospective water uses, identifies water supplies, and estimates facility needs and costs. The plan also describes water problems and opportunities, outlines significant environmental concerns and water issues, and offers program and policy recommendations.

8. **Texas Water Development Board, Water For Texas, Today and Tomorrow, November 19, 1992.** This report updates the 50-year plan for the state of Texas. This summary document provides details on the current and prospective water uses, identifies water supplies, and estimates facility needs and costs. The plan also describes water problems and opportunities, outlines significant environmental concerns and water issues, and offers program and policy recommendations. Additionally, the document outlines proposed future Texas Water Development Board actions and key policy recommendations to local, State, and Federal entities in the area of water management.

9. **Texas Water Commission, A Plan For Meeting the 1980 Water Requirements For Texas - 1961.** This report addressed potential flood damages and water supply issues. Pertinent data to the Pecan Bayou watershed included discussion of a reservoir on Jim Ned Creek at the Jim Ned Creek site.

10. **Texas Water Commission, The State of Texas Water Quality Inventory, August 1992.** This report was prepared in accordance with Section 305(b) of the Clean Water Act and describes the status of the state waters based on the most recent four years of monitored surface and ground water quality data. An overview is provided discussing water quality trends, attainment of surface water quality standards, relative impacts of pollutants from various sources, and water bodies where additional actions are needed. Surface water quality data is summarized for individual streams, river, reservoir, bay, estuary and Gulf of Mexico segment. Groundwater quality within each major river basin is described.

11. **Brown County Water Improvement District Number One, Hydrologic Study of Lake Brownwood and the Pecan Bayou Watershed, March 1965**. This study investigated the current and likely future dependable yield from Lake Brownwood.

12. **Brown County Water Improvement District Number 1, November 1979, Investigation of Lake Brownwood Dam.** This study analyzed the adequacy of the existing dam. The study concluded the foundation of the existing dam appears to be stable, and the spillway does not appear to be in immediate need of rehabilitation. The study further concluded the existing dam is hydraulically inadequate for the design storm. Their recommendations included raising the dam to elevation 1470' (from existing elevation 1449'), and a modification to the outlet works to allow for water supply by pipeline. Modifications to the spillway were not warranted at that time.

STUDY AREA

Based on the problems and opportunities identified in the March 1994 Reconnaissance Report, flooding has been a reoccurring concern within the Pecan Bayou watershed, particularly along Pecan Bayou and Willis Creek in the city of Brownwood. The following is a physical description of the Pecan Bayou and Willis Creek study areas as seen in Figures 3 and 4 for purposes of this feasibility study. It has been refined on the basis of the reconnaissance findings and the willingness of the local sponsor.

Pecan Bayou

The study area is defined as the approximate 500-year flood plain along Pecan Bayou from a point approximately 2,000-feet upstream of U.S. Highway 377, extending downstream to FM 2129, about 5,000 feet downstream of the confluence with Willis Creek, a distance of approximately 22,000-feet. Within the study area, Pecan Bayou is a gently, to a moderately, meandering waterway having a top width ranging between 135- to 215-feet and depths between 22- and 32-feet. The slope is estimated to drop 0.53 feet per thousand foot (2.8 feet per mile) of channel. About 500-feet upstream of U.S. Highway 377, a concrete structure is located across the bayou, and produces a permanent pool of water for the adjacent Riverside Park. Pecan Bayou flows in a south-southeasterly direction through the eastern portion of the city of Brownwood in the study area, and is bounded by FM 2525 (Williams Ranch Road) to the north and Atchison Topeka and Santa Fe Railroad to the south. In addition to U.S. Highway 377 near the upstream study area limit, there are two bridges crossing Pecan Bayou: Woodson Road and the Atchison Topeka and Santa Fe Railroad. The majority of the development is located in the upstream portion of the study area.

Willis Creek

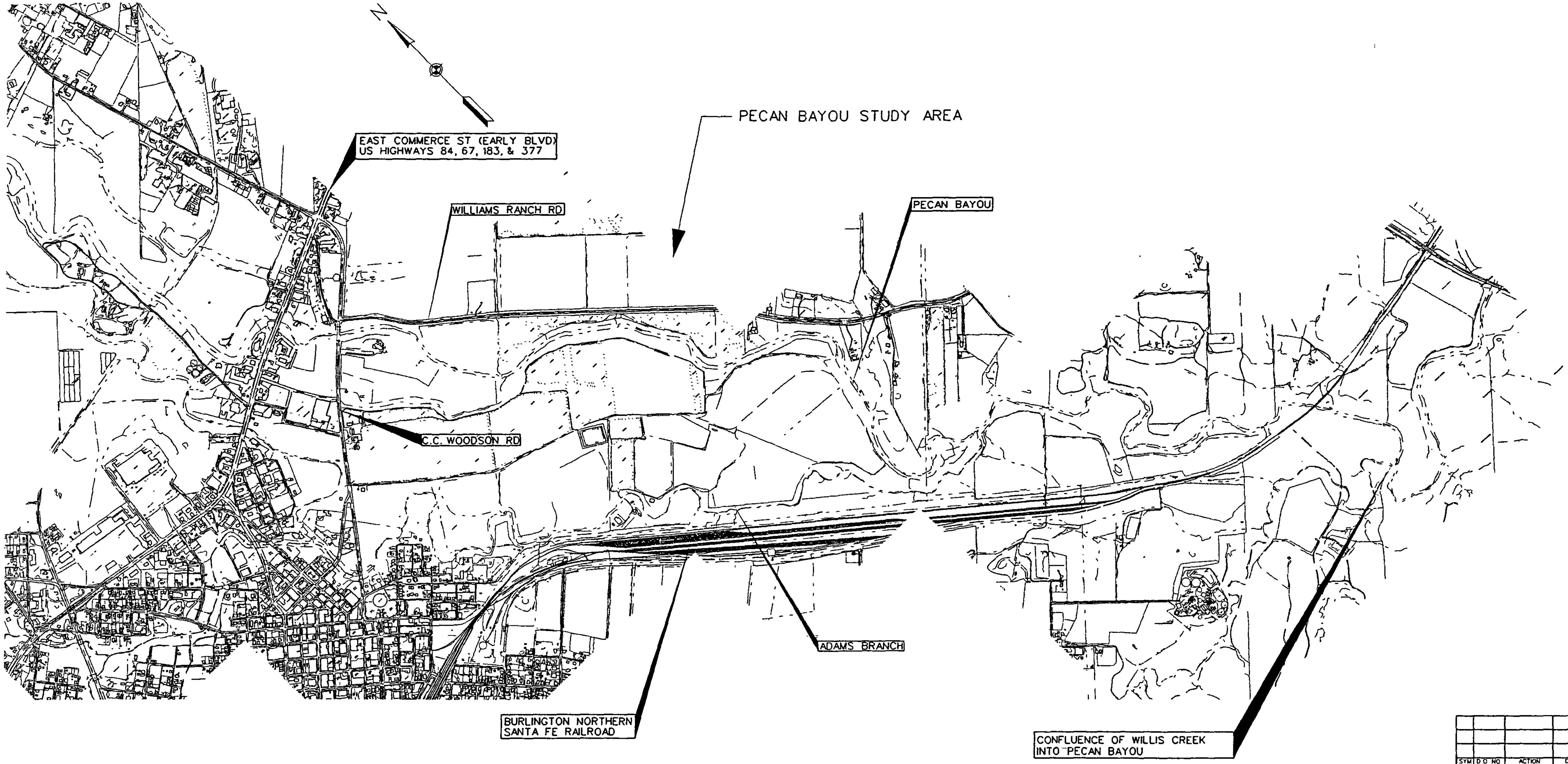
Willis Creek originates about five miles southwest of Brownwood and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. The study area is defined as the Standard Project Flood Plain along Willis Creek beginning at its confluence with Pecan Bayou and extending upstream a distance of about 24,000 feet terminating near Asbury Street. Within the study area, Willis Creek is a gently, to a moderately, meandering waterway having a top width ranging between 40- to 135-feet and depths between 4- and 11-feet. The slope is estimated to drop 2.92 feet per thousand foot (15 feet per mile) of channel. Willis Creek flows in an easterly direction through the southern portion of the city of Brownwood to the confluence with Pecan Bayou. Willis Creek has 3 concrete box culverts, at Austin Street, 4th Street, and 14th Street. Located further upstream is a wooden railroad bridge and an arched rock culvert bridge at Crockett Drive. The majority of the study area is bordered on at least one side by residential development. Figure 4 displays the Willis Creek study area.

A principal tributary to Willis Creek is South Willis Creek. South Willis Creek originates a few miles due south of Brownwood and proceeds in a northerly direction to NRCS floodwater retarding site "Brownwood Laterals #4A", at which point the total drainage area is 0.84 square miles. Below the damsite, it proceeds in a northerly direction to its confluence with Willis Creek. Another prominent feature of this watershed is the NRCS floodwater retarding site "Brownwood Laterals #4B", which is situated on the "Country Club" tributary. South Willis Creek has a drainage area of 10.7 square miles.

DESCRIPTION OF THE WATERSHED AND STUDY AREA

History

North American Indians were the first inhabitants of Brown County. The first white men can be traced back to the early 1700's when Spanish missionaries and soldiers inhabited the area. The first Anglo-Americans to enter the county were under the leadership of Captain Henry Stephenson Brown in 1828 seeking to recover livestock stolen by Indians. Within ten years, land surveyors came into the county running landlines and staking corners for citizens of Texas who lived in the eastern and southeastern sections of the state. Brown County was established in 1865 by the state legislature. The City of Brownwood was created on August 27, 1856 and organized on March 21, 1857. The original city was located approximately one mile east of the present location on the banks of Pecan Bayou and moved to its' present location in 1867. Brown County remained a frontier settlement for twenty years following the coming of the first settlers. The settlers made their homes in the valleys near the streams. There were no towns other than the county seat and it was a primitive frontier village. A land boom, precipitated by increasing land prices speculation and the extension of the Sante Fe Railroad into Brownwood, brought an increase in the population and gave added impetus to the agricultural economy of Brownwood and surrounding areas. Between 1880 to 1900, the open range of Brown County was converted to farmland. By 1920, Brownwood was the largest cotton-buying center west of Fort Worth. During the 1920's, there was an oil boom in the area resulting in even greater economic growth. In September 1940, Brownwood was selected as the site for a training center for the U.S. Army. The original military campsite of 2,000 acres expanded to include nearly 5,000 acres, and the original area of 60,000 acres expanded to nearly 122,000 acres. By March 1941, the population of Brownwood has risen to 23,500, up from 14,000 the previous year.



SYM	D O NO	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

REVIEWED BY: E MARTINEZ

COLORADO RIVER BASIN
FEASIBILITY STUDY

PECAN BAYOU STUDY AREA

SUBMITTED BY:

TERRI L. NOLEN, P.E.
CHIEF, CIVIL SECTION

SOL. NO

DATED:

CONTR. NO

DRAWING NUMBER

SHEET NO
OF

FIGURE NO.
3

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

CADD FILE NAME: fig3.DGN

Climatology and Precipitation

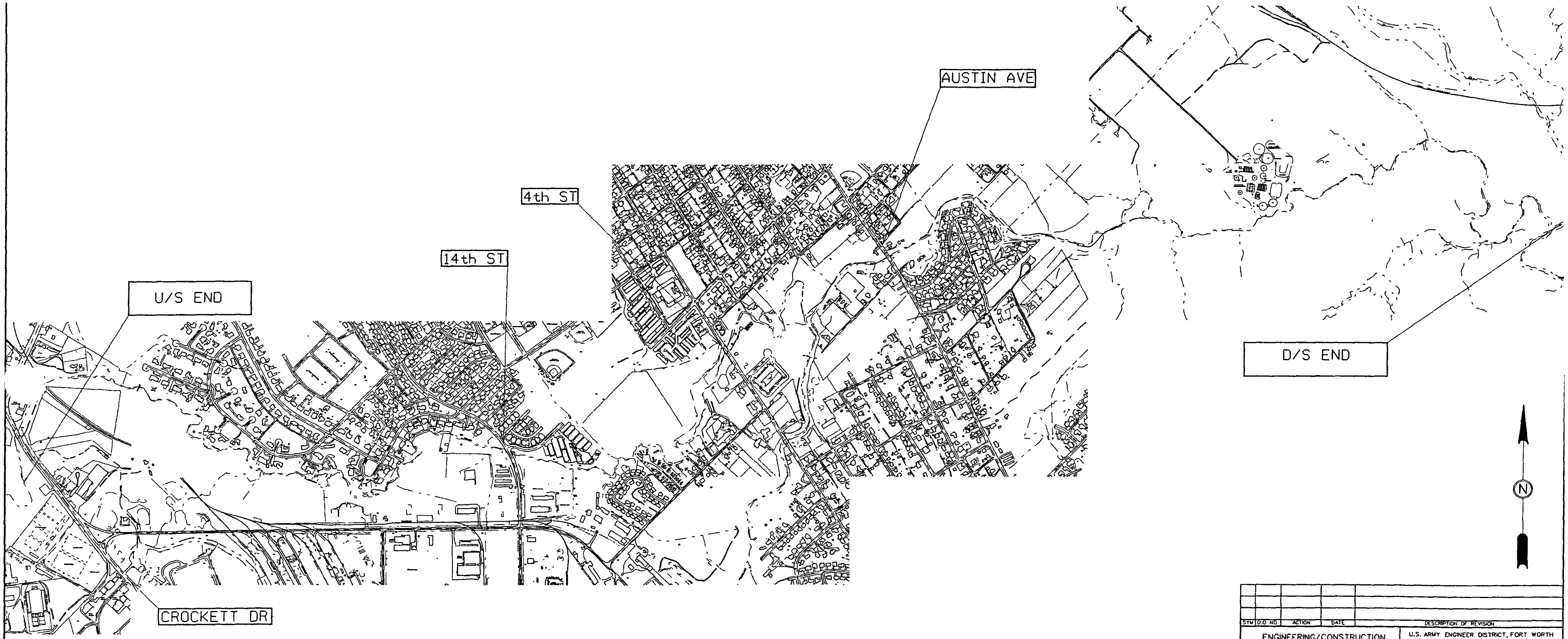
The Pecan Bayou watershed has a temperate climate characterized by hot summers and cool winters. Freezing temperatures and snowfall are occasionally experienced during the passage of cold high-pressure air masses from the northwestern polar regions and the continental western highlands. The mean annual temperature in the watershed is about 65 degrees (F). Temperatures range from a maximum of 114 degrees to a minimum of minus 6 degrees. January has an average minimum daily temperature of about 32 degrees. August, the warmest month, has an average maximum daily temperature of about 97 degrees. The average length of the growing season between killing frosts is about 247 days.

The storms that cause precipitation in the Pecan Bayou watershed are of three general types: thunderstorms, frontal storms, and tropical storms originating in the Gulf of Mexico. Most of the precipitation in the basin results from storms of the first two types, although the tropical type storms occur frequently, primarily during the period June to November. The mean annual precipitation over the Pecan Bayou watershed is about 27 inches and varies from about 23 inches in the headwaters region to about 29 inches near the mouth. Snowfall is an insignificant portion of the total precipitation, except for a few exceptionally heavy snowfalls (such as the eight-inch fall in February 1966). Annual precipitation recorded at Brownwood has varied from a maximum of 46.00 inches in 1919 (although in 1990 the total rainfall of the area was 45.97 inches) to a minimum of 10.86 inches in 1921. The normal seasonal distribution of rainfall over the watershed is generally favorable for agricultural purposes. Daily precipitation extremes include 11.49 inches, on 26 April 1990; 6.60 inches, on 5 October 1959; and 5.90 inches, on 1 June 1988. The maximum calendar month precipitation was 14.66 inches in April 1990, closely followed by the 12.90 inches in June 1959.

Physiography and Geology

The Pecan Bayou watershed lies principally within the Central Texas section of the Osage Plains Section of the Central Lowlands Physiography province. The watershed portions that are upstream and downstream from approximately the Brown-Coleman County line are principally within the Rolling Plains and the North Central Prairies land resource areas, respectively. The watershed is characterized by plateaus in maturity and later stages of erosion with areas of well-developed and rapid drainage and moderate relief, ranging from relatively smooth plains to sharply eroded valleys. The watershed soils are sandy loams, clay loams, clays, and stony soils, ranging from slightly acid to neutral to slightly calcareous, and from dark brown to reddish brown to grayish brown. The soils within the mainstream valleys are alluvial deposits. The watershed elevations vary from about 2,370 feet above mean sea level (along the headwater divide, about fourteen miles south of Abilene), to about 1,150 feet above mean sea level (at the confluence of Pecan Bayou with the Colorado River, about eight miles west of Goldthwaite). Limestones, shales, sandstones, and conglomerates of Pennsylvanian, Permian, and Lower Cretaceous ages underlie the watershed. The Pennsylvanian age stratum regionally dips toward the west-northwest at a rate of about 60 feet per mile. Although small faults and flexures are common in the Pennsylvanian strata, geologic maps prepared by the Texas Bureau of Economic Geology, and other structural geology maps reviewed during the study, do not delineate any significant faults in the study area. Brownwood lies within seismic zone 0, according to the Uniform Building Code Seismic Zone Map, as presented in EM 1110-2-1806, dated 31 July 1995, subject: Earthquake Design and Evaluation for Civil Works Projects.

A geotechnical field investigation and laboratory testing of soil and rock samples collected from borings drilled along Pecan Bayou and Willis Creek in the study area was completed. Alluvial deposits consisting of silt clays (CL to CH) and sands (SP-SM) were identified in borings drilled along Pecan Bayou. Alluvial deposits consisting of clays (CH), sandy clays (CL), clayey sands (SC), and sandy, clayey gravels were identified in borings drilled along the Willis Creek. The primary materials in the area of Willis Creek are soft shales and hard limestone of the Pennsylvanian age Strawn Group. Some borings drilled along Willis Creek identified rock at depths as shallow as 2 to 2.5 feet below ground surface, whereas other borings encountered alluvial deposits to depths of 17.8 to 20 feet (total depth drilled). It is anticipated that any excavation along Willis Creek would encounter significant quantities of rock.



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DESIGNED BY: L. MENDOZA
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COLORADO RIVER BASIN
FEASIBILITY STUDY

WILLIS CREEK STUDY AREA

SUBMITTED BY:
TERRI L. NOLEN, P.E
CHIEF, CIVIL SECTION

SOL. NO
DATED:
CONTR NO.
DRAWING NUMBER
SHEET NO.
OF
FIGURE NO. 4

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

CADD FILE NAME: FIG4.DGN

Wildlife Resources

The Pecan Bayou watershed is situated in the West Cross-Timbers vegetational region, which is characterized by rolling to hilly topography with moderate relief from relatively smooth plains to sharply eroded valleys. Surface drainage is rapid. Mesquite/oak woodlands and short to mid-height grasses occur on the slopes and hilltops, with denser stands of oak, elm, hackberry, ash, and pecan at the lower elevations along local drainages. Agricultural fields and pasture are intermingled with undeveloped land. A wide range of wildlife inhabits the watershed, including game and non-game mammals, birds such as raptors, waterfowl, wading birds, shorebirds, perching and songbirds, reptiles and amphibians.

Pecan Bayou

Tree species along the Pecan Bayou include pecan, live oak, elm, willow, red mulberry, and hackberry. The understory includes greenbriar, trumpet creeper, and various species of tree seedlings and saplings. Portions of the banks of Pecan Bayou are heavily wooded with large pecan trees. This band of riparian habitat provides an important corridor that is utilized by deer, raccoons, squirrels, and other mammals, and a wide variety of birds, including raptors, waterfowl, shorebirds, and songbirds There are also overhanging tree limbs providing shade, and woody debris along the waterway that provides basking sites for turtles and snakes. In some areas, the riparian has been cleared to the stream bank for agricultural and limited commercial development.

Willis Creek

The trees along this corridor of Willis Creek include large, mature live oaks, red oaks, pecans, willows, hackberries, and elms. The overstory provides considerable shade for the creek. The developed areas along the creek have very little or no understory. The undeveloped areas and creek banks are vegetated with dense patches of greenbriar, honeysuckle, and sapling willows, oaks, pecans, live oak, elms, and hackberry. Although in an area of urban development, the riparian corridor of Willis Creek provides important habitat. The wildlife species present are generally limited to those tolerant of relatively high levels of human disturbance. These include mammals such as raccoons, opossums, fox squirrels, and small rodents. Numerous species of reptiles and amphibians are also present. Bird species range from the red-tailed hawk to various perching and songbirds such as chickadees, warblers, and sparrows. Several species of duck have also been observed utilizing Willis Creek.

Aquatic Resources

Pecan Bayou

The character and composition of the aquatic resources of Pecan Bayou have been influenced by prior projects such as the construction of Lake Brownwood and the two overflow spillways near the City. The fishery and other aquatic resources have been altered through past projects along the Bayou. Below U.S. 67, large concentration of rough fish such as gar and carp occur in deep pools, and green sunfish, largemouth bass, and catfish (bullhead, channel, and flathead) are abundant throughout the system. A list of fish species known to occur in Pecan Bayou and immediate tributaries is presented in Sub-Appendix G, Table 1. A recent survey documenting the populations of fish or other aquatic organisms inhabiting the Pecan Bayou system is not available.

Pecan Bayou varies in width from 40 to 60 feet and the water depth ranges from being very deep (>10 feet) to very shallow. Riffle, pool, and run complexes throughout the system are abundant. The banks of the bayou are heavily eroded in some areas, with tree roots and exposed bare soil. Slopes of the banks vary from moderate to extremely steep. Aquatic habitat in the bayou includes overhanging vegetation, dead fallen limbs and trees, animal burrows, root wads, undercut banks, limestone outcrops, and mixed sorted gravel beds.

Willis Creek

Willis Creek is a major tributary of Pecan Bayou. This tributary flows into Pecan Bayou just east of the city. Throughout most of the year, Willis Creek is a low gradient stream exhibiting low flow conditions. During storm events, water levels in the creek quickly rise and fall. Stream flows during these events are of extremely high velocity. The banks of Willis Creek are fairly unstable and highly erosive as evidenced by many areas of sloughing and undercutting. Consequently, many large fallen trees can be found throughout the system. Many homes, backyards, and stormwater drainage pipes in the upper reaches of Willis Creek appear to be threatened by erosion.

The stream morphology of Willis Creek is extremely variable. The composition of stream banks and bottom ranges from being solid limestone outcrops and unconsolidated boulders to clay and heavy deposits of silt. Riffle, pool, and run complexes are numerous. There are also many areas along the upper reaches of Willis Creek where residents have landscaped their backyards using pavers, stones, or concrete right into the stream. On a walking survey conducted by the Corps and the United State Fish and Wildlife Service there were 22 riffles, 22 runs and 27 pools identified in the Willis Creek study area. The riffles averaged approximately 53 feet in length, were about 7 feet width, and had a depth that was roughly 1 foot. The runs averaged approximately 95 feet in length, were about 8 feet wide, and had a depth that was about 1.5 feet. The pools identified were roughly 280 feet long, about 16 feet wide, and were about 4 feet deep. As for overall percentage composition of each of the morphologic features, pools dominated the distribution by providing slightly over 70% of the stream length, runs comprised about 19% of the stream length, and riffles made up the remaining 11% of the stream length. At least four man-made low water weirs exist and responsible for creating a significant amount of the pool habitat in the upper reaches of Willis Creek, also several or the residents have constructed bridges across the stream.

Aquatic habitat throughout Willis Creek is of high quality in the stretches of the creek that have not been improved. Aquatic habitat in this system includes root wads, overhanging vegetation, boulders and mixed sorted gravel beds, rock outcrops, undercut banks, and animal burrows. The composition of the fish and other aquatic organisms in Willis Creek has not been documented but probable would resemble those of the aquatic invertebrates and macroinvertebrates found in the adjacent Pecan Bayou.

A survey of the study area by Corps and United States Fish and Wildlife Service personnel indicated that there were no jurisdictional wetlands along Willis Creek.

Threatened and Endangered Species

According to the U. S. Fish and Wildlife Service, the following species are listed as either threatened or endangered within the Pecan Bayou watershed. They are the threatened Concho Water Snake (*Nerodia paucimaculata*), and the endangered Black-capped vireo (*Vireo atricapillus).* No black-capped vireo habitat is known to occur along Pecan Bayou. The Concho Water Snake Recovery Plan (Fish and Wildlife Service 1993) indicates populations appear to be fairly continuous to about the FM 45 Bridge upstream from the mouth of Pecan Bayou. However, no Concho Water Snakes have been found in Pecan Bayou study area. Any recommended plan within the study area is not anticipated to affect any Federally listed threatened or endangered species.

Cultural Resources

The cultural resources work for the Pecan Bayou study was conducted in accordance with and partial fulfillment of the U.S. Army Corps of Engineers obligations under the National Historic Preservation Act Of 1966 as amended (PL 89-665). Other obligations include the Archeological And Historical Preservation Act Of 1974, as amended (PL 90-190), and Executive Order no. 11593 the "Protection And Enhancement Of The Cultural Environment".

The study area is an erosional plateau of Cretaceous sandstone and sandy outcrop with ridges oriented in a north-south direction. Most of the lowlands are erosional except for the "mesquite flats" which lie in depositional areas. Prehistorically it was a savannah with timber along the streams. The land was probably overgrazed, resulting in the uplands growing cactus, mesquite, and scrub oaks. Soils in the project area are Frio, Rochelle, and Callahan-Throck. Frio is a deep, nearly level soil on floodplains along major streams. Rochelle is a deep, gently sloping soil found in the uplands. The Callahan-Throck association consists of stony, moderately deep and deep soils on uplands.

No systematic archeological or structural inventories have been completed within the study area as part of this feasibility study. A number of small archeological surveys near the confluence of Willis Creek and Pecan Bayou were completed in 1978 and 1980 by local archeologists. Eight archeological properties on Willis Creek and Pecan Bayou near their confluence just downstream of the Brownwood water treatment plant were recorded (publication unknown). In 1987, the Travis County Archeological Society recorded six additional archeological properties, two of which were historic period cemeteries (no publication). Previous efforts on other portions of Pecan Bayou have recorded numerous archeological properties and several historic buildings and structures. Discovered in the area west of the Willis Creek study area were two burned rock middens, a human burial associated with a rockshelter destroyed during highway construction in Brownwood, and the testing of several sites on a tributary of the Pecan Bayou. A single site has been recorded south of the Willis Creek study area along a small tributary leading to Willis Creek. A portion of the middle and all of the lower portions of the study area is likely to contain buried archeological resources. A proper assessment of the potential for buried archeological resources will require a systematic investigations using primarily heavy mechanical equipment to conduct trenching investigations. Systematic shovel testing will also be employed as appropriate to specific areas. All inventory and survey efforts will be required during the plans and specification phase and prior to construction in order to limit project redesign, realignments, or costly mitigation efforts.

Water Quality

The most recent surface water quality survey completed by the state of Texas indicates that water quality problems associated with elevated levels of inorganic nitrogen, phosphorous, and fecal coliform have been measured on Pecan Bayou in the area downstream of the confluence of Willis Creek to the Colorado River. The presence of this material is likely influenced by the Brownwood wastewater treatment facility. There are no known water quality problems identified in Pecan Bayou upstream of Willis Creek.

In January 1994, a raw sewage spill occurred resulting in a large fish kill in Pecan Bayou. The County Health Department issued a warning not to consume fish caught from the two streams. Water samples taken at the site contained ammonia up to 6 mg/L (anything over 3 mg/L can be toxic). Additionally, the dissolved oxygen was 0.7 mg/L.

Groundwater in Brown County is located in shallow and discontinuous, low permeability zones of sandstone and limestone in all Cretaceous, Permian, Pennsylvanian and Ordovician groups. Additional occurrence of groundwater is in the terrace and floodplain alluvium of Pecan Bayou. The alluvial zones are in hydraulic connection with the stream, its major tributaries, and large lakes. The source of water in the alluvial aquifer is chiefly the infiltration of rainfall on the surface of the alluvium. Most measured water levels in floodplain wells range from 13 to 41 feet. It is anticipated that during dry periods Pecan Bayou acts as a means for groundwater discharge into the river with the opposite being true for wet periods. Under natural conditions, most of the alluvial groundwater is discharged into surface water bodies, evaporated, or transpired. During periods of high river stage, ground water that normally seeps into the river is backed up in the alluvium, and a large part goes into riverbank storage along with some of the floodwater. Water levels in the alluvium rise during these periods, particularly near the river. When the river stage declines, groundwater again discharges into the river, and the water levels decline.

Reports of oil-field brine contamination (excessive concentrations of sodium, chloride, magnesium, and calcium) of groundwater have been documented in the past. The sources of contamination have most likely resulted from overflow of surface pits, discharging wells, and leaking oil-field waste lines.

Hazardous, Toxic, and Radiological Wastes (HTRW)

An initial assessment was performed within the study area. Reviews of the regulatory records, aerial photographs, and interviews indicated that the area has been historically commercial and agricultural in nature. In recent years there has been light residential development south and more extensive residential development north of the study area.

The observed water clarity during a visual inspection of Willis Creek during a low runoff period appeared to range from stained in upper reaches to quite murky in the lower reaches. Visual inspection of Pecan Bayou revealed a general murkiness throughout its extent. Possible hazardous, toxic, or radioactive wastes noted during the site inspection consisted of the presence of numerous 55-gallon drums behind the 3M Company facility. The visual survey did not necessarily preclude the possibility of other sites containing hazardous, toxic, or radioactive wastes from this inventory, as access to the Pecan Bayou and its tributaries was limited in many places.

Five Comprehensive Environmental Response Compensation and Liability Act Information System (CERCLIS) sites were identified from the database searches of hazardous, toxic, and radioactive activities in the study area. All five sites had a "no further action status", indicating cleanup or neutralization of the sites had taken place. Research of the Resource Conservation and Recovery Act Information System (RCRIS) database revealed no apparent HTRW releases in or near the study area.

There are two locations in the study area of concern. The first is at the USDA Pecan Field Station to the west of Pecan Bayou where a former municipal solid waste landfill had reportedly been operated within an old channel of Adams Creek. On March 20, 2000, the Fort Worth District conducted field investigations that concluded the waste to be municipal solid waste confined to the old channel alignment for Adams Creek.

The second site is a Formerly Used Defense Site (FUDS) at former Camp Bowie, just south of Willis Creek. This area's history of possible uncontrolled dumping in open pits, combined with its proximity to the creek, presents a possible environmental risk. On March 21, 2000, the Tulsa District, Corps of Engineers, which is responsible for FUDS work, initiated a site investigation, which included soil and groundwater sampling, surface water and sediment sampling from Willis Creek, and an electromagnetic survey to locate the limits of the landfill area. The results of the soil and groundwater showed only a few samples with elevated concentrations of specific contaminants. Based on the findings of the investigation this site may be closed under the Texas Natural Resource Commission (TNRCC) Risk Reduction Standard 3, which allows soils that pose no threat to human health and the environment to remain in place.

Socio-Economic Characteristics

The city of Brownwood, incorporated in 1948 is located in west central Brown County, about 120 miles west of downtown Fort Worth. The four-county area population (Brown, Mills, Callahan, and Coleman) in 1960 totaled 49,582, of which 23,345, or about 47 percent was urban. By 1990, the population of the four-county area had grown to 60,471, of which 37,308 (or 62 percent) lived in urbanized areas. The population in Brown County in 1990 was 34,371, with 18,387 in Brownwood alone. This shows a trend of increasing total population for the area at a rate of over 350 people per year and increasing urban population rate of over 450 people per year. As is common in most agricultural areas, changes in farm methods, increased mechanization, and improved transportation resulted in a decrease in rural population. The estimated population in 1998 was 19,534 for Brownwood and 36,889 for Brown County. The study area is a major manufacturing, trade, distribution, and finance center. Other significant contributors to the economy are agriculture, department of correction facilities, oil and gas operations, timber, and tourism. The principal manufacturing activities of the area consist of the manufacture of clothing, plumbing fixtures, brick and tile, farm machinery, leather goods, feed and cottonseed oil products, and the processing of foods, dairy products, meat and poultry. Manufacturing activities in Brownwood employ approximately 4,000 workers. Agriculture is of major importance and contributes substantially to the economy of the area. The principal farm crops grown are wheat, peanuts, and hay. There is also a large production of pecans along the streams. Livestock raised in the area include beef cattle, sheep, goats, and swine. Production of wool and mohair is of major importance. The 1999 county unemployment rate was 3.6 percent, compared to the state unemployment rate of 4.3 percent. This low unemployment rate is reflected in the areas personal income. Personal income is considered the most comprehensive measure of economic activity available in this study since it maintains a close and generally constant relationship with the gross national product. The average per capita income for the county in 1998 was approximately $18,800 compared with the state average of approximately $25,400. The estimated population in 2000 exceeded 19,800 in Brownwood and 37,000 in Brown County.

Recreational Resources

The *1990 Texas Outdoor Recreation Plan* (TORP) remains the most comprehensive source of information available for determining recreational needs in the state of Texas. The City of Brownwood and Brown County are within the 19-county West Central Texas-Planning Region 7.

Region 7 has over fifty-seven thousand surface acres of lakes. Because of the even distribution of these lakes and their associated parks, most cities have good access to recreational facilities. Significant streams in the region include the various forks of the Brazos River, Pecan Bayou, and the Colorado, Leon, and Wichita rivers. The U.S. Army Corps of Engineers facilities at Hords Creek Lake and Proctor Lake are very popular with Region 7 residents and visitors. Three state parks and a historical park are major attractions that draw recreationists from all over the state, particularly the West Texas and Dallas-Fort Worth areas.

There are nearly twenty-one thousand acres of recreation land in Region 7 distributed among 217 parks. With about fifty-eight acres of recreation land per thousand population, the region ranks well below the statewide average of 209 acres per thousand. Local governments supply the largest proportion of the total recreation land with 37 percent. The next largest supplier is the Corps of Engineers, at 31 percent, followed by the commercial sector, 21 percent, and the Texas Parks and Wildlife Department, 10 percent. Local governments also furnish the largest number of parks at 133.

In 1995 the most popular activities in Region 7, in terms of percentage of the population participating, were projected to be walking for pleasure, picnicking, pool swimming, playground use, freshwater fishing, and freshwater swimming, respectively. Region 7 residents are active outdoors and enjoy a variety of recreational activities. Activities projected to exceed the statewide rate in user occasions per capita in 1995 are freshwater boating, camping, all types of freshwater fishing, hunting, lake use, picnicking, freshwater swimming, baseball and off-road vehicle use.

The existing Lake Brownwood is also valuable for recreational activities. Commercial, private, and state park recreational facilities located along Lake Brownwood shoreline area, excluding lands, has a present estimated value of over $30,000,000. Much of the area around lake Brownwood has been developed for cabin, cottage, lodge encampment, commercial recreational businesses, and permanent homes. The area provides many cabins and camping areas, swimming areas, docks, and boathouses. The shoreline area is undergoing extensive subdivision and the amount of recreational improvements is expected to increase considerably in the future. The Lake Brownwood shoreline area includes the Lake Brownwood State Park area. The State Park area involves an area of about 500 acres and includes cabin areas, playground areas, and facilities for boating, fishing, swimming, picnicking, and dancing. Lake Brownwood has a normal water surface area of about 7,500 acres and a shoreline distance of about 95 miles.

Future population growth in Region 7 should not greatly impact recreation resources. Lakes, parks, and cities are fairly well distributed throughout the region, and, except for Abilene, there are no large population centers that would create undue impacts.

Water Supply

Major suppliers in the upper basin are the Lower Colorado River Authority, Colorado River Municipal Water District, and irrigation companies in the lower basin. Ground water supplies are obtained from six major and several minor aquifers through the basin. The Ogallala, along with the Edwards-Trinity and Dockum aquifers, occur in the upper part of the basin. The Edwards-Trinity and Lipan aquifers are in the west-central part. The Trinity, Edwards-Balcones and Carrizo-Wilcox are in the south-central basin along with several minor aquifers. The Gulf Coast aquifer occurs in the lower basin.

In response to Senate Bill 1, passed by the 75th Texas Legislature in 1997, the Texas Water Development Board created 16 regions across the state to plan for the water needs of the state for the next 50 years. The area in and around Pecan Bayou is situated within Region F which consists of 32 counties in west Texas. Six major rivers and 17 water supply reservoirs characterize the region's surface water hydrology. Additionally, 11 aquifers lie within the region, six of which provide significant water to the region. There are three providers of regional wholesale water in Region F; the Colorado River Municipal Water District, Brown County Water Improvement District Number One, and the Upper Colorado River Authority.

As of 1998, Region F had an estimated population for 2000 of 638,000 or 3 percent of Texas's population. Nearly half of the regions population is situated in three metropolitan areas (Midland, Odessa and San Angelo). The cities of Brownwood and Big Spring have populations greater than 20,000. The region's population is expected to increase to 922,000 over the next 50-year planning horizon.

The total water demand for the region is expected to increase from 881,500 acre-feet per year in 2000 to 900,200 acre-feet per year in 2050. The main water users presently are: irrigated agriculture (73.6%), municipal (16.7%), mining (3.5%), livestock (2.8%), power (2.4%), and manufacturing (1.0%). Only municipal, manufacturing, and power water demands are projected to increase by 2050 while the remainder is projected to remain the same or decrease.

The current supply of water for Region F consists of reservoirs, ground water, local supplies, and wastewater reuse. Ground water is by far the largest source (66%) and reservoirs contribute 21% of the supply. The latter have an estimated supply of 243,600 acre-feet per year in 2000 and are expected to decrease due to sedimentation to 235,100 acre-feet per year in 2050.

PROBLEM IDENTIFICATION

As previously discussed, the primary study area is defined as the 500 year Standard Project Flood Plain along Pecan Bayou from U.S. Highway 377, extending downstream to the confluence of Willis Creek, a distance of approximately 7,500 feet. On Willis Creek, the study area begins at its confluence with Pecan Bayou and extends upstream a distance of about 22,000-feet, terminating near Asbury Street.

HISTORY OF FLOODING

The city of Brownwood has experienced frequent flooding along Pecan Bayou and Willis Creek ever since the first settlers arrived at it banks in the early 1800's. Flooding has been documented as early as 1868. Recorded "great" floods occurred in 1868, 1875, 1900, 1908, and 1915. One "great" flood occurred in September 1900, which was prior to the construction of Lake Brownwood.

This flood had a stage of 21.7 feet and an estimated peak discharge of 150,000 cubic feet per second. Discharges high enough to cause significant damages tend to occur in clusters of consecutive or non-consecutive years. The years following the wet cycle are usually characterized by smaller, non-damaging flows. Flood events have been modified by the construction of Lake Brownwood (1932) and Hords Creek Reservoir (1948). However, these projects have only partially eliminated flooding problems along Pecan Bayou and its tributaries.

Since urbanization is a major contributing factor to the current and future flooding problems, it is important to examine floods that have occurred in more recent years. Significant floods have occurred along Pecan Bayou in 1980, 1982, 1984, 1986, 1990, 1991, and 2000.

Heavy rains (five inches) over a five-day period culminated on December 31, 1984, when three inches of rainfall produced excessive runoff from the already saturated ground. Numerous roads, houses, apartments, and school buildings were inundated to various depths. Property losses were reported to have exceeded $500,000. Rainfall from this flood occurred below the control of Lake Brownwood, as the spillway was not overtopped in this event.

On June 5, 1986 up to six inches of rain caused Pecan Bayou to overflow its banks. The high water from Pecan Bayou forced the closure of several major and minor streets in the central business district of the city. Some minor structure flooding was reported but no estimates on these losses are available.

In 1990, major portions of central Texas experienced heavy rainfall over a 3-week period as a result of a cold front mixed with an upper level low and produced two frontal type storms. Between April 17 and May 4, rainfall amounts up 18 inches were recorded in the Brownwood area. The rain led to record water levels at Lake Brownwood. Water surged more than 7 feet over the lake's emergency spillway. By mid-morning of April 26, most routes from the city were severed and a normally bustling traffic circle was submerged under several feet of water. Brownwood remained underwater for 5 days with 7 feet of water covering most of the commercial area along highway 377. In the city of Brownwood, 528 homes and 70 businesses were either damaged or destroyed. Public and agricultural facilities were also damaged. In addition to the economic damages from this flood, two residents of the city were swept away by the flood and drowned. Flood damages and associated costs were estimated to exceed $10 million (1990 cost estimate). On May 2, 1990, the President declared the State of Texas a major disaster area due to the severe flooding.

In December 1991, Brownwood, as well as large portions of southeastern Texas (Austin, San Antonio), experienced record rainfalls. The Brownwood area received between 8 and 12 inches of rain. Brown County and the city of Brownwood reported a total of 213 local dwellings affected by flood waters, with 26 totally destroyed and another 125 sustaining major damage; 10 residences sustained approximate damages of $100,000. Businesses sustained over $580,000 in damages in this flood event, not including lost revenue. The damage to residential structures around Lake Brownwood included 92 homes severely damaged, 26 homes with minor damage, 26 mobile homes destroyed, 32 mobile homes with major damage, and 14 mobile homes with minor damage. Brown County was declared a disaster area in December 1991.

In the early morning hours of June 15, 2000, an isolated storm dumped over 8 inches of rain on the city of Brownwood causing street and residential flooding, and necessitating the evacuation of 125 city residents, including some by helicopter. Official reports indicated that all of the creeks and streams in Brownwood had overflowed their banks. Along U.S. Highway 377 at the east of the city, public streets and commercial parking lots were flooded and roads were closed to traffic. At the peak of the storm, the city's emergency sirens were activated to warn residents of the flooding conditions. Consideration was given to requesting assistance from the National Guard, but the storm abated before such a call was initiated. Flood damage and costs estimates are not available on this storm.

Pecan Bayou Flood Pattern

Under normal flows, waters remain within the channel and "trickles" over the dam. During a flood event, water initially spills out of Pecan Bayou immediately upstream of the Riverside Park dam. During storm events, the dam, by impeding flow, is a contributory factor to water leaving the channel. From Lake Brownwood, water traverses in a southerly direction, crossing U.S. Highway 377, inundating the northeastern portion of town. At this point, a portion of the overland flow is captured by the Pecan Bayou slough. Pecan Bayou slough is the remnant of the historical Pecan Bayou channel that has over geological time, meandered to its existing location. The Pecan Bayou slough originates slightly upstream of U.S. Highway 377. It flows generally southeast, somewhat parallel to Pecan Bayou until it joins Pecan Bayou approximately 2 miles downstream. The slough is fairly shallow and has many meanders as it flows along the eastern edge of the city. The existing bottom width of the slough is approximately 10 to 15 feet and it is highly vegetated along its banks. The existing hydraulic capacity is limited.

Entering the Pecan Bayou slough downstream of U.S Highway 377 is Adams Branch. This small tributary originates west of Brownwood, and flows in an easterly direction through the northern portion of the city. Hydraulically speaking, storm events within the Pecan Bayou watershed are the controlling factor on the lower reaches of Adams Branch. However, localized precipitation within the Adams Branch watershed may cause flooding without any inundation from Pecan Bayou. Regardless, given the existence of a NRCS stream bank erosion structure on Adams Branch, and in accordance with the desire if Brownwood, this feasibility study does not address flooding specific solely to Adams Branch.

EXISTING FLOOD DAMAGES

The Hydrologic Engineering Center-Flood Damage Assessment Program (HEC-FDA) was utilized to facilitate the evaluation of flood damages. The program integrates hydrologic, hydraulic, and economic analyses through application of the Monte Carlo simulation. This program computes the expected annual damage value while accounting for uncertainty in the basic value. Expected annual damage (EAD) is the mean damage obtained by integrating the damage exceedance probability curve for the damage reach. The damage exceedance probability curve results from the discharge-exceedance probability, stage-discharge and stage-damage functions derived at each reach index location.

Estimates of flood damages are determined as a single, annualized expected value, and on a probabilistic basis. The classical nomenclature describing the relative risk of flooding has been revised to reflect the actual probability, rather than the average recurrence interval, of flood events. For example, the commonly used term "100-year frequency flood", meaning that flood which stands a one percent chance of being equaled or exceeded in any given year period will hereafter be described as the "1 percent annual chance exceedance (ACE) flood." For convenience, the new probabilistic nomenclature will be abbreviated as "1 percent ACE flood."

Using the appropriate water surface profiles, the depth of water at each structure within the study area is calculated for the 100, 50, 20, 10, 4, 2, 1, 0.4, 0.2, and 0.1 percent ACE flood events (or the 1-, 2-, 5-, 10-, 25-, 50- 100-, 250-, 500-, and 1000 year flood, respectively.) These depths were combined with the damage susceptibility factors and estimated values to estimate expected annual damages.

Damage susceptibility factors used to estimate flood damages include the number and type of structures within the flood plain, the value of the property, the elevation at which the structure begins to sustain measurable damages, and a flood depth-damage relationship. Existing damageable properties were classified into major damage categories as follows: residential (single and multifamily dwellings and associated private vehicles), commercial, and railroad facilities. A floodplain inventory was completed within the study area. This inventory included enumeration of the numbers and types of structures. Further, the appraised value of each structure was obtained from the Brown County Tax Appraisal District. Determining replacement cost less depreciation is basically the same as the Cost Approach (outlined in the Corps of Engineers guidelines) for deriving values from an appraisal standpoint. This information has been continually updated as the study has progressed and remains current for the purposes of this report.

Pecan Bayou

A total of 737 damageable structures were identified within the 0.2 percent ACE limits Pecan Bayou and Adam Slough study limits as indicated in Table 1. Approximately 70% of the total investment values identified are commercial, while 11% are residential. The total floodplain investment within the .2 percent ACE limits is valued at about $ 81.5 million based on May 2000 prices and level of development. The average structure value of single-family residences is about $14,000 and constitutes only 11 percent of the total flood plain investment, while the average value of commercial structures (structure and contents) average $130,000 and accounts for approximately 70 percent of the total flood plain investment.

The remaining percentage represents losses in multifamily units, privately owned vehicles, and railroad tracks. Table 2 shows the cumulative estimated single occurrence flood losses under existing conditions for Pecan Bayou.

Table 1

Estimated Investment Value of Pecan Bayou and Adams Slough Flood Plain Properties

($1000's, based on May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	274	$35,000	$22,000	$57,100
Single Family	450	$6,200	$3,000	$9,100
Multi-Family	13	$300	$100	$400
Subtotal	737	$41,500	$25,100	$66,000
Vehicles				$1,100
Rail				$13,000
Total Investment	**737**	**$41,500**	**$25,600**	**$81,500**

Table 2

Pecan Bayou Cumulative Estimated Single Occurrence Flood Losses Structures, Contents under Existing Conditions

($1000's, based on May 2000 price and development level)

Flood Event	Commercial		Single-Family*		Multi-Family		POV	Rail	Total
	Damage	No.	Damage	No.	Damage	No.	Damage	Damage	Damage
20%									
10%	$ 710	38	$ 60	17	$ 20	1	$ 20	$ 30	$ 840
4%	$ 4,710	99	$ 550	61	$110	9	$ 140	$ 180	$ 5,690
2%	$ 7,850	129	$1,130	126	$180	9	$ 250	$ 480	$ 9,890
1%	$11,200	141	$1,960	222	$240	9	$ 410	$1,020	$14,830
0.4%	$19,020	204	$4,400	366	$350	13	$ 810	$2,950	$27,530
0.2%	$24,070	274	$6,540	450	$390	13	$1,130	$4,770	$36,900

*Includes mobile homes.

Willis Creek

A total of 322 damageable structures were field identified within the .2 percent ACE limits of Willis Creek with the majority of the structures identified are single family residential as shown in Table 3. The total estimated value of the flood plain investment is about $37.3 million, based on May 2000 prices and level of development. Residential values constitute 88 percent of the total flood plain investment with an average value of $65,500 for single-family residences and their contents. The remaining investment of $2.5 million stems from privately owned vehicles. Table 4 presents a summary of the cumulative number and type and the associated damages of affected structures and vehicles, by flood occurrence not accounting for risk and uncertainty.

Table 3

Estimated Investment Value of Willis Creek Flood Plain Properties

($1000's, May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	5	$ 400	$ 300	$ 700
Single Family	296	$ 19,400	$ 9,700	$ 29,100
Multi-Family	21	$ 3,300	$ 1,700	$ 5,000
Subtotal	322	$ 23,100	$ 272	$ 34,800
Vehicles		$ 2,500		$ 2,500
Total Investment		$ 25,600	$ 272	$ 37,300

Table 4

Willis Creek Cumulative Estimated Single Occurrence Flood Losses Structures, Contents under Existing Conditions

($1000's, based on May 2000 price and development level)

Flood Event	Commercial Damage	No.	Single-Family* Damage	No.	Multi-Family Damage	No.	All Structures Damages	No.	POV Damage	Total Damage
20%			$ 606	52	$ 266	4	$ 872	56	$ 23	$895
10%			$2,889	138	$ 521	6	$3,410	144	$ 155	$3,565
4%			$5,006	205	$ 746	9	$5,751	214	$ 438	$6,189
2%		1	$6,385	242	$ 924	13	$7,309	255	$ 696	$8,006
1%	$ .5	3	$7,280	260	$1,065	13	$8,347	276	$ 882	$9,229
0.2%	$30.4	5	$8,350	296	$1,225	21	$9,591	322	$1,305	$11,939

A predominance of residential structures is found within the 10% ACE flood plain and constitutes 95 percent of the expected annual damages. Based on May 2000 prices, expected annual flood losses to structures in the study area total an estimated $956,700 in damage. It is estimated that an .2 percent ACE event could cause structure and content damages of about $11.8 million. This would represent a loss of about 45 percent of the .2 percent ACE floodplain investment. The one-percent ACE could produce flood approaches the damages of $9.2 million, while the 10 percent event produces about $3.6 million in damages. A predominance of residential structures would be subject to flooding in all the flood zones. Overall, about 85 percent of the damageable property identified would be subject to the one-percent ACE flood event. Properties within the 10 percent ACE flood event constitute about 45 percent of the total number of structures potentially damaged along Willis Creek. Table 5 displays the existing expected average annual damages in the Willis Creek study area.

Table 5

Existing Expected Average Annual Damages

($1000's, based on May 2000 prices and level of development)

Property Type	**Annual Damages**
Single-Family	$ 755.2
Multi-Family	$ 131.2
Commercial	$ 1.4
Vehicles	$ 68.9
Total	**$ 956.7**

RECREATIONAL OPPORTUNITIES

The need for recreational outputs within the watershed is limited, particularly in the City of Brownwood. Those recreational facilities typically associated with local flood damage reduction projects such as parks, playgrounds, hike and bike trails are in sufficient supply in Brownwood and the immediate vicinity. Given that the City did not desire such features to be included in any recommended plan, further studies regarding recreation opportunities were not pursued.

ECOSYSTEM RESTORATION OPPORTUNITIES

This feasibility study does not include any detail investigations of ecosystem restoration opportunities. The local sponsor did not desire such features to be included in any recommended plan. Therefore, further studies regarding ecosystem restoration were not pursued.

WATER SUPPLY OPPORTUNITIES

On a regional basis, the total water demands in Region F exceed the currently available supplies throughout the 50-year planning period. Shortages increase from 170,000 acre-feet per year in 2000 to 200,000 acre-feet per year in 2050. Most of these shortages result from large irrigation demands that cannot be met by ground water during drought conditions. Flood control reservoirs were eliminated from consideration during the reconnaissance phase. No measures were pursued during the feasibility phase to address the water supply needs of the Region. Therefore, further studies regarding water supply were not pursued.

PLAN FORMULATION

Plan formulation is the process of developing and evaluating alternatives that meet planning objectives and avoid planning constraints. This chapter details this process of stating the planning objectives and constraints, the initial screening of measures, the evaluation of alternatives, and the selection of the recommended plan.

PLANNING OBJECTIVES

Planning objectives are an expression of public and professional concerns about the use of water and related land resources resulting from the analysis of existing and future conditions in the study area. The planning objectives for the period of analysis between the years 2005 to 2050 are as follows.

1. Reduce flood damages to structures and their contents as well as vehicles, along Pecan Bayou and Willis Creek within the city of Brownwood.

2. Reduce the potential for loss of life associated with inundation, high velocities, isolation, and/or overtopping of roads and bridges, along Pecan Bayou and Willis Creek within the city of Brownwood.

3. Reduce flood damages to public facilities such as roads, bridges, utilities, schools, churches, etc., along Pecan Bayou and Willis Creek within the city of Brownwood.

4. Reduce the public and private costs associated with flood fighting and recovery along Pecan Bayou and Willis Creek within the city of Brownwood.

5. Minimize environmental and social disruptions, and preserve or enhance fish and wildlife habitat.

6. Reduce business and commercial losses resulting from a loss of production and/or economic activity for establishments along Pecan Bayou and Willis Creek within the city of Brownwood.

7. Improve the overall health, safety and quality of life of the citizens of city of Brownwood, the state of Texas, and the United States of America.

8. Establish a National Economic Development Plan (NED).

PLANNING CONSTRAINTS

In development of flood damage reduction alternatives, the following constraints or limitations were identified to direct plan formulation efforts such that beneficial impacts would be maximized and adverse effects would be minimized:

1. Alternatives will be limited to the study area within the city of Brownwood along Pecan Bayou and Willis Creek.

2. The city of Brownwood will not support any alternative on Pecan Bayou which involves the removal of Riverside Park dam.

3. The formulation of alternatives that reduce flood damages and costs in one area should not result in the measurable increase in the extent and magnitude of flooding in another area.

4. The formulation of alternatives must avoid adverse effects to significant ecological and environmental resources. If avoidance is not feasible, adverse effects to these resources must be minimized. Unavoidable adverse effects to these resources must be mitigated.

5. The formulation of alternatives must avoid adverse effects to significant cultural resources; and if avoidance is not feasible, then adverse effects to cultural resources must be minimized. Unavoidable adverse effects to cultural resources must be mitigated.
6. The formulation of alternatives should avoid areas that are either known or suspected to be contaminated and/or contain hazardous, toxic, and radioactive waste.
7. The formulation of alternatives must avoid adverse effects to occupied land.
8. The formulation of alternative must avoid adverse aesthetic and visual effects.
9. Total annual benefits must equal or exceed total annual costs for a plan to be implemented.
10. The recommended plan must be generally acceptable to the public.
11. The recommended plan must have a local non-Federal sponsor.

PLAN FORMULATION RATIONALE

Plans are formulated to meet planning objectives and to adhere to the constraints. The following paragraphs discuss the technical, economic, environmental, and social criteria used to develop the formulated alternatives to meet the stated study objectives.

Technical Criteria

In order to develop a plan that would satisfy the primary objective of reducing flood damages and costs within the study area, the following technical criteria were adopted for use in developing, evaluating, and comparing alternative plans:

1. The plan should be effective and efficient with regard to alleviating the specified problems and achieving the specified goals.
2. The plan must be technically feasible using engineering methods and equipment available in the study region.
3. Plans should be adequate to provide a project life of at least 50 years.
4. Existing facilities should be utilized to the maximum extent possible.
5. The plan is to be complete within itself and not require additional future improvements other than normal replacements, and operation and maintenance.
6. The plan is to be designed using engineering criteria taken from appropriate Corps of Engineers engineering and design manuals and regulations related to flood damage reduction alternatives.

Environmental and Social Criteria

Plans formulated under Federal directives should be consistent with protecting the existing environment by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the proposed project area. Structural and nonstructural measures must be evaluated in accordance with guidelines established by the National Environmental Policy Act of 1969 (Public Law 91-190), as amended, and the P*rinciples and*

Guidelines for Water and Related Land Resources Implementation Studies, as developed by the U.S. Water Resources Council, dated July 1983. The following environmental and social criteria were considered:

1. Protect against possible loss of life, property, and hazards to the health and safety of area residents, and preserve, maintain, or enhance community cohesion and desirable community and regional growth.

2. Preserve and/or enhance social, cultural, educational, and aesthetic values as well as historical and cultural attributes of any sites within the project area.

3. Promote the development of areas of natural beauty and human enjoyment and protect areas of valuable natural resources.

Economic Criteria

The National Economic Development (NED) objective is the maximization of the economic worth of alternative plans as set forth in *Principles And Guidelines For Water And Related Land Resources Implementation Studies*. The NED objective is to increase the nation's output of goods and services and improve economic efficiency. For flood damage reduction projects, this objective relates to a plan's capability to prevent flood damages and costs (economic benefits). The amount that a project's economic benefits exceed the project cost (when both are expressed in annual terms) is defined as the net benefits of the plan. In the plan formulation process, the plan that meets the planning objectives and falls within the planning constraints, yields the greatest net benefits, and best meets the objective of NED.

Economic feasibility of a plan is measured as a relationship of benefits-to-costs. Benefits are the monetary savings due to damages prevented, reduction in the cost of emergency services, and the reduced disruption of the local economy. These benefits are subsequently annualized to represent a yearly benefit applicable for the life of the project. The project cost, are also annualized so as to represent an annual project cost, applicable for the analysis period of the project. The annual benefits and the annual costs are then related in a benefits-costs ratio (BCR). To be economically feasible, a plan must have benefits which equal or exceed costs, i.e., a BCR equal to or greater than 1.0.

To meet the Federal guidelines for planning water resource projects, the following economic criteria were followed:

1. All plans must be economically feasible, which dictates that the plan's flood reduction benefits must exceed the cost of the plan. Measures for mitigation, restoration, and protection of environmental resources must be justified based on a combination of tangible and intangible benefits.

2. The alternative being selected as the recommended plan should reasonably maximize benefits over costs consistent with protecting the Nation's environment, while meeting the planning objectives and avoiding the planning constraints. Each separable unit or purpose of a given alternative must provide benefits at least equal to its costs.

3. Alternatives will be evaluated using the current price level, a 50-year period of analysis, and the current Federal discount rate for water resource projects as determined by the U.S. Department of Treasury.

4. Annualized costs include the cost of operation, maintenance, repair, replacement, and rehabilitation (OMRR&R).

SCREENING OF ALTERNATIVES

Various alternatives were identified and evaluated in an effort to achieve the stated planning objectives and to adhere to the constraints. The alternatives can be categorized as the "no action" alternative, nonstructural alternatives and structural alternatives. The initial screening of alternatives eliminated those alternatives that obviously failed to meet the minimal technical, economic and/or environmental criteria, and evaluated in terms of completeness, effectiveness, efficiency, and acceptability. Completeness is the extent to which an alternative provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. Effectiveness is the extent to which an alternative alleviates the specified problems and achieves the specified objectives. Efficiency is the extent to which an alternative is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment. Acceptability is the workability and viability of the alternative with respect to acceptance by the State and local entities, and the public and compatibility with existing laws, regulations, and public policies. Those alternatives remaining after the initial screening receive additional detailed investigations.

No Action

The "no action" alternative would not recommend that any type of project, nonstructural or structural, be implemented. While the no action alternative would not require the expenditure of Federal funds, adoption of this alternative implies acceptance of the existing and future flood damages and other adverse impacts caused by continued flooding. Although flood insurance would partially compensate for flood damages, they would still be incurred. The financial burden of nearly $ 1.0 million in annual flood damages for flood fighting and recovery costs, public damages, the potential loss of life, and the overall threat to health and safety would continue under the no action alternative. The no- action alternative does not meet the previously stated planning objectives. This alternative would be unacceptable to the city of Brownwood if a feasible alternative were identified.

Nonstructural Alternatives

Nonstructural measures attempt to avoid flood damages by exclusion or removal of damageable properties from flood prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather they affect floodplain activities. Nonstructural alternatives include the following; regulation of the flood plain use, flood forecasting and warning (temporary evacuation) flood-proofing, elevating structures, relocating structures, permanent evacuation.

Regulation of Floodplain Uses

Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within an existing floodplain. The technique of controlled land use is particularly helpful in planning for future development but is of limited use in present developed areas. Effective regulation of the floodplain is dependent on developing enforceable ordinances to insure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes. Zoning regulations permit prudent use and development of the floodplain in order to prevent excessive property damage, expenditure of public funds, inconvenience, and most important of all, loss of life, due to flooding. Subdivision regulations guide the division of large parcels of land into smaller lots, and typically require the developer to show compliance with subdivision regulations, zoning ordinances, the local land use or master plan, and other regulations. A subdivision ordinance would require installation of adequate drainage facilities, prohibit encroachment into floodway areas, require the placement of critical streets and utilities above a selected flood elevation, and building lots or structures above a selected flood elevation, normally one foot above the 100-year floodplain elevation. Building codes specify the building design, materials and construction methods used for both construction of new buildings or repair of flood-damaged structures.

The city of Brownwood currently holds about $4.4 and $20.1 million of Federal Emergency Management Agency's, National Flood Insurance Program (NFIP) and Write-Your-Own flood insurance protection, respectively. The City has been enrolled in NFIP's Regular Program since June 20, 1975. Since the inclusion into this program, Brownwood has enacted and enforced numerous floodplain land-use restrictions, regulation, zoning ordinances, subdivision regulations, and building codes. While these measures will not reduce flood damages the majority of the existing structures in the study area, they are important management tools. Regardless, this does not warrant further evaluation. It should be noted that the city of Brownwood will be required to complete and implement a flood plain management plan within one-year of the completion of any flood damage reduction plan recommended and implemented by the Corps of Engineers.

Flood Forecast and Warning

Flood forecast and warning involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in evacuation of persons and some personal property. Notification of impending flooding can be by radio, siren, individual notification, or by more elaborate means such as remote sensors to detect water rise levels and automatically warn residents. These measures normally serve to reduce the hazards to life and damage to portable personal property. Flood warning and emergency evacuation should be considered as part of any flood control plan. This alternative also includes the use of flood forecasting to revise the current flood control-operating plan of area lakes to provide additional flood control protection.

The city of Brownwood has a highly effective and efficient workforce that mobilizes during storm events to visually monitor rainfall and river stages. Additional information from Lake Brownwood provides ample time for the mobilization of resources to address Pecan Bayou. Flood forecasts and warnings are not considered further in this study.

Flood-proofing

Flood-proofing structures involves providing watertight coverings for door and window openings, sump pumps to drain seepage, sealing of cracks, steel bulkheads on brick walls (flood shields) to close off entrances, coating walls of structures with a waterproof membrane. Flood proofing is generally applicable where flooding is of short duration, low velocity, infrequent, of shallow depths, and requires significant modifications to structures. For water levels that are lower than the first floor of a home, flood proofing would certainly be a possibility. However, if a sustained water level in excess of one foot of the first floor elevation, the structural stability of a watertight home becomes a critical factor. A flood-proofed structure generally cannot withstand hydrostatic pressures when floodwaters rise three feet above the lowest floor. In addition, flood proofing introduces uncertainties in the degree of protection, since the owner must be present (or awake) to close off windows, doorways, etc. Additional shortcomings include not protecting public facilities such are roads, bridges and utilities, and the continued threat of road closures and the isolation of residents trapped in there homes and businesses. The feasibility of flood-proofing is based on the cost and availability of the structure, the number of structures along the alignment, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Construction of individual flood-proofing around specific structures or small groups of structures is normally considered cost prohibitive unless the individual structure(s) is very valuable and/or has cultural significance and is prone to frequent flooding.

While flood proofing would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, the past flooding depths and velocities do not address the planning objectives or criteria previously discussed in providing feasible flood protection. Therefore, flood proofing will not be considered further for either the Pecan Bayou or Willis Creek study areas.

Elevating Structures

This alternative avoids flood damages by elevating damageable property. Elevating is most practical for structures that have access below the first floor (i.e. piers and columns), are light enough to be jacked, and are relatively small. Wood frame structures are particularly suited for rising. Rising structures with slab foundations or basements is not generally economically feasible. The design of the foundation walls or piers must withstand forces from flowing water to ensure lateral stability of the structure. Furthermore, elevating structures has similar limitations as flood proofing, namely protecting public facilities, the continued threat of road closures, and the isolation of residents trapped in their homes and businesses. While elevating structures would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, it does not address the planning objectives or criteria previously discussed. The feasibility of elevating structures is based on the cost and availability of real estate, the number of structures along the alignment to be elevated, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Elevation of structures is normally considered cost prohibitive unless the individual structure is very valuable and/or has cultural significance and is prone to frequent flooding. Based on the type and number of commercial structures located along the channels, elevating structures will not be considered further for either the Pecan Bayou or Willis Creek study areas.

Permanent Evacuation

This alternative (also known as the "buy-out") involves the acquisition, demolition, the removal of structures from the flood plain, and the relocation of residents to flood-free housing. The practicality of evacuation depends on several factors. They include the frequency and severity of flooding, the willingness of residents to move out of the flood plain, the availability of flood-free housing, the value of the property, and the need for areas of a more compatible floodplain use such as parks or nature areas. Permanent evacuation can be a very effective means of reducing flood damages, as well as public damages and costs.

Past investigations have demonstrated that permanent evacuation is typically cost effective only up to and including the 10% ACE flood plain. Within the Pecan Bayou study area, there are a total of 46 structures (34 commercial, 12 residential) within the 10% ACE flood plain. Within the Willis Creek study area; flood damages to structures and their contents begin at about the 20% ACE flood event. There are a total of 56 structures within the 20% ACE flood plain (52 single family residential and 4 multifamily residential), and 144 structures within the 10% ACE flood plain (138 single family residential and 6 multi-family residential). Given that the majority of structures within the Pecan Bayou study are commercial, the difficulty and high costs of relocating commercial establishments, and Brownwood's reluctance to risk the loss of revenue, permanent evacuation will not be considered further on Pecan Bayou. However, further investigation of permanent evacuation would be required on Willis Creek.

Structural Alternatives

Structural alternatives are designed to control, divert, or exclude the flow of water from flood prone areas to the extent necessary to reduce damages to property, hazard to life or public health, and general economic losses. The structural measures considered most appropriate in dealing with the character of the flood problems encountered in the study area are modification to Lake Brownwood, detention, levees and floodwalls, hydraulic channel improvements including bridge modifications, and diversion.

Detention

This alternative consists of constructing one or more structures to provide flood control storage to detain peak flood flows and lessen downstream flood damages. Detention is used to temporarily impound floodwaters for later release when the downstream conditions permit. The feasibility of this measure depends heavily on the volume and timing of the flood flows, and the availability of an impoundment site capable of providing sufficient storage. Additional costs would also be incurred to mitigate for adverse environmental impacts.

Detention structures of various sizes and capacities, located at two sites above Lake Brownwood, were previously investigated for Pecan Bayou during the reconnaissance study. Out of the ten different detention configurations investigated, none had a benefit-cost ratio greater than 0.2, well below that required for economic feasibility. Conditions in the city of Brownwood are similar to what they were at that time, therefore no additional efforts were viewed as warranted for a detention reservoir in this feasibility study, and this alternative was screened from further consideration.

In the upstream reaches of Willis Creek, there are several detention structures that were constructed by the NRCS. These structures retain a substantial percentage of the rainfall in the upper Willis Creek watershed. For this study, a brief hydraulic analysis of a new detention reservoir near Crockett Street was conducted. Investigations revealed insufficient space available, and this alternative was not considered further.

Levees and Floodwalls

Levee systems traditionally provide high levels of protection to flood prone areas but often require substantial amounts of real estate between the stream and the structures being protected unless an existing levee is in-place and only a small strip of real estate is required. Floodwalls (usually made of concrete) are used in lieu of levees in situations where the acquisition of real estate for the levee or other topographic problems may be prohibitive. The feasibility of either of these measures is based on the cost and availability of real estate, the number of structures along the levee alignment, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Construction of individual levees or floodwalls around specific structures or small groups of structures is normally considered cost prohibitive unless the individual structure is very valuable and/or has cultural significance and is prone to frequent flooding.

A levee system alternative was considered along both Pecan Bayou and Willis Creek. However, the close proximity of structures to the waterways and the lack of available space, made a levee physically infeasible because of the anticipated high relocation cost associated with removal of the structures where the levees would be constructed. Floodwalls, which require less real estate acquisition, are historically much more expensive than any other alternative, either structural or nonstructural. Based on the minimal benefit-cost ratios estimated for other flood protection alternatives, and because of the large number of structures and length of the floodplain, the floodwall alternative would be prohibitively expensive. The non-Federal sponsor and residents of the area expressed that this was the least desirable solution to the flooding problems, due to the adverse aesthetics of this alternative. Therefore, levees and floodwalls were eliminated from further consideration.

Hydraulic Channel Improvements and/or Bridge Modifications

This measure consists of modifying an existing channel by either increasing the cross-sectional area of the stream channel and/or an existing bridge (widening and/or deepening), straightening and realigning the stream channel, and/or reducing the friction losses of an existing channel through concrete lining. The design of the channel modification can vary significantly and is primarily based on the topography of the existing stream channel and the existing development of properties within the floodplain. The study area of Pecan Bayou and Willis Creek meets the minimum flows, minimum drainage area, and urban drainage criteria required under current policies. Other factors to consider in the design of these hydraulic channel improvement alternatives include the existence of known or potential significant ecological and cultural resources as well as contaminated material.

The hydraulic channel improvement alternative investigated in the 1994 reconnaissance study on Pecan Bayou was a grass-lined channel beginning at U.S. Highway 377 and extending downstream a distance of 7,500 feet. Based on a Reconnaissance level of investigation, the channel would have a bottom width of 50-feet with side slopes of 1 vertical on 3 horizontal (1V:3H). The modified channel slope would average about 0.02 percent. Excavation of both the channel side slopes and bottom would be required. The banks would be steeper at the Woodson Road Bridge to enable the improved channel to have a smooth transition in and out of the bridge; further, the existing bridge concrete columns would be encased to compensate for the channel excavation under the bridge. There is also some minor utility relocation required. The project first cost was estimated at $2,845,000 (January 1994 price level). Annual costs and expected annual benefit were estimated at $257,000 and $320,300, respectively. The benefit-cost ratio was 1.2 to 1.0. Accordingly, a hydraulic channel improvement on Pecan Bayou warranted further investigation.

The hydraulic channel improvement investigated in the 1994 reconnaissance study on Willis Creek was a grass-lined channel. The first segment of the improved channel begins near Asbury Street and extends approximately 1,670-feet downstream of 4th Street, a total distance of about 13,530-feet. The downstream portion of this segment has a bottom width of 40-feet; the upstream portion has a bottom width of 50-feet. Side slopes are 1V:3H throughout this segment. The second segment begins near Austin Avenue (note an unimproved segment lies between the improved segments) and extends a distance of about 1,670-feet downstream. This segment of the channel has a bottom width of 30-feet, and side slopes of 1V: 3.5H (left bank) and 1V:3H (right bank). This alternative would require the modification of the 14th Street Bridge by adding four 7x9-foot barrels to the existing box culverts (five 10x10-foot). Several water and sewer line relocations, in addition to other utilities would also have to be relocated. The project first cost was estimated at $3,798,400 (January 1994 price level). Annual costs and expected annual benefit were estimated at $356,700 and $1,167,600, respectively. The benefit-cost ratio was 3.3 to 1.0. Accordingly, a hydraulic channel improvement on Willis Creek warranted further investigation.

City Officials expressed the concern that the FM Road 2126 bridge, which crosses Pecan Bayou about five miles downstream of U.S. Highway 377, was an obstruction and thus, creating a backwater effect. The substantial roadway embankments, on both the left and right side of the channel, essentially block most of the overbank flow areas, thereby preventing storm water from effectively passing beneath the bridge. These embankments do not affect the capacity of the waterway during common storm events, but cause a significant increase in the water surface elevation during rare events. However, because of the distance upstream to the damage centers within the city of Brownwood, this increased water surface dissipates to only a few hundredths of a foot at Woodson Road. Preliminary investigations revealed that the cost of increasing the capacity of this bridge would not be justified by the negligible reduction in flood damages for such rare flood events in the study area. Therefore, this alternative was not studied in detail.

ALTERNATIVES INVESTIGATED

As a result of the previous screening of alternatives, specific alternatives were identified as warranting further study on Pecan Bayou and Willis Creek.

Pecan Bayou

Based on the initial screening of nonstructural and structural alternatives, only a hydraulic channel improvement was identified as warranting further study. A nonstructural plan was investigated through an array of alternatives but was not determined economically feasible in complying with planning objectives and constraints of this study. Additionally, permanent evacuation was not desired by the city of Brownwood given the significant number of commercial properties located in the frequently flooded areas. In addition, an alternative, not previously discussed, the removal or modification to the Riverside Park dam, was investigated. Presented below is the result of the additional detailed investigation of these alternatives.

Removal or Modification to Riverside Park Dam

As previously discussed, the advent of flooding along Pecan Bayou occurs when, during storm events, the dam impedes flow causing flood water to break out of the channel upstream of the dam, and inundate the developed areas. However, the impact of removing the dam on the flood profile was not investigated in any detail. The city of Brownwood would not support the removal of the dam and the associated adverse impacts to Riverside Park. Therefore, removal of the dam was not considered further.

In an attempt to provide greater conveyance over the dam, the potential for widening the top width of the dam (and subsequently the channel) was investigated. Preliminary results revealed that only marginal reductions in flood damages could be achieved by widening the dam. Consequently, modifications to the dam were not considered further.

Hydraulic Channel Improvements

As previously discussed, a hydraulic channel improvement was determined to be feasible on Pecan Bayou during the reconnaissance study. The objective of the hydraulic channel improvement is to produce improved tailwater conditions downstream of the dam thereby minimizing the amount of flow leaving the channel upstream of the dam.

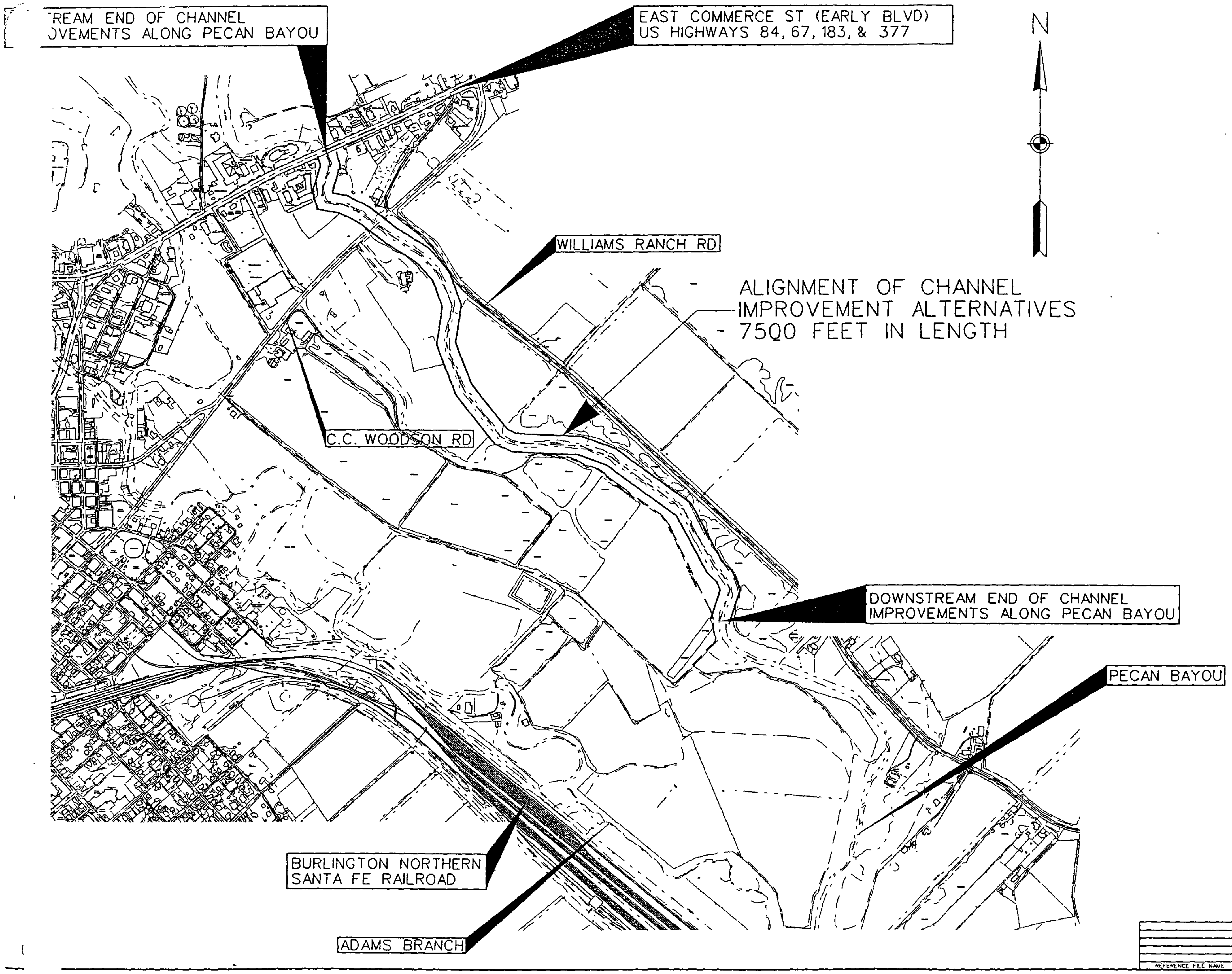
A re-analysis of the original Pecan Bayou channel improvement alternative produced significantly different results. This alternative, as seen in Figure 5, consisted of a grass-lined channel beginning at U.S. Highway 377 and extending downstream a distance of 7,500 feet. The channel would have a bottom width of 50-feet with side slopes of 1V:3H. Excavation of both the channel side slopes and bottom would be undertaken. The banks would be steeper at the Woodson Road Bridge to enable the improved channel to have a smooth transition in and out of the bridge; further, the existing bridge concrete columns would be encased to compensate for the channel excavation under the bridge. Utility relocations would also be required. The current estimated total project cost and annual cost of this alternative is $3,670,700 and $277,000, respectively. Expected annual benefits are estimated at $4,300, for a benefit cost ratio of 0.02.

Based on the analysis, the hydraulic channel improvement on Pecan Bayou will not be feasible. The estimated flood damage reduction benefits associated with a channel improvement have been drastically revised downward since the reconnaissance study. The reconnaissance study estimates of flood damage reduction benefits were determined with limited information and analyses, and outdated methodologies. During this feasibility study, the analyses benefited from additional, detailed information. Further, improvements in the hydrologic, hydraulic, and flood damage estimate models used in this feasibility study identified inaccuracies in the reconnaissance study estimates. Once corrected, it became clear the channel improvement would not significantly reduce flood damages.

While a larger channel may potentially produce greater flood damage reduction benefits, the larger channel will also have considerably greater construction costs. Assuming environmental mitigation costs could be reduced by limiting excavation to single, alternating-bank as well as by avoiding the channel bottom by using a "terrace", realistically the incremental increase in benefits, relative to the incremental cost increase, would not be sufficient to raise the benefit cost ratio to 1.0. While potential benefits related to the avoidance of traffic disruption costs, flood fighting and recovery costs, and public damages are not quantified, they are not likely sufficient to provide economic feasibility to this alternative. Therefore, a hydraulic channel improvement on Pecan Bayou was eliminated from further consideration.

Overflow Swale

In order to provide additional conveyance, an overflow swale was also investigated. The swale investigated consisted of a grass lined channel beginning at an oxbow on the Pecan Bayou slough immediately north of Woodson Road that rejoins the main stem of Pecan Bayou about 8,600-feet downstream as shown in Figure 6. The swale has a bottom width of 100-feet, with side slopes of three horizontal to one vertical. Normal flows would continue to flow through Pecan Bayou slough, until about the 2-year frequency event which would spill into the swale and pass through the study area without causing any property damage. The swale would have a very low slope to the point where it rejoins Pecan Bayou, and then it would need to drop quickly into the existing channel. This portion of the new channel would need to be protected from erosion by the use of concrete riprap on the banks and invert. Figure 6 displays this alternative.



LEGEND

CHANNEL CENTERLINE – - – - – - -

SYM	D O NO	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

REVIEWED BY: E. MARTINEZ

COLORADO RIVER BASIN
FEASIBILITY STUDY
PECAN BAYOU
CHANNEL IMPROVEMENT ALTERNATIVE

SUBMITTED BY
TERRIL NOLEN, P.E
CHIEF, CIVIL SECTION

SOL. NO.

DATED.

CONTR. NO.

DRAWING NUMBER

SHEET NO
OF

FIGURE NO.
5

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

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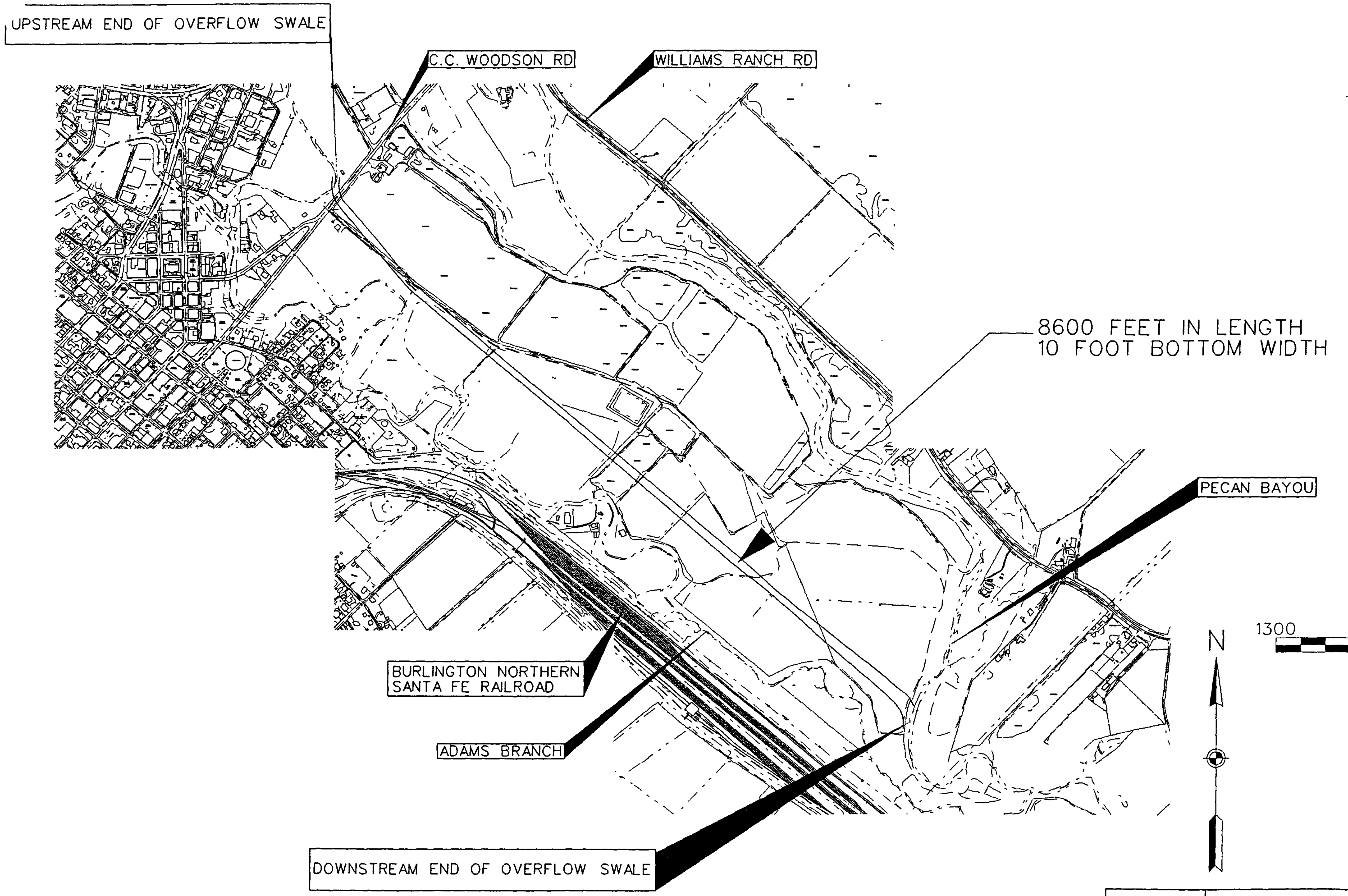

LEGEND

EXCAVATION LINE

SYM	D O NO	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L MENDOZA

DRAWN BY: L MENDOZA

REVIEWED BY: E MARTINEZ

COLORADO RIVER BASIN
FEASIBILITY STUDY

PECAN BAYOU
OVERFLOW SWALE ALTERNATIVE

SUBMITTED BY:
TERRIL NOLEN, P.E.
CHIEF, CIVIL SECTION

SOL. NO

DATED:

CONTR NO.

DRAWING NUMBER

SHEET NO
OF

FIGURE NO.
6

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

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The estimated total and annual cost of the swale alternative is $8,951,500 and $626,000, respectively. Expected annual benefits are estimated at $120,500, representing a reduction in flood damages of about 12%. The resulting benefit-cost ratio is 0.19, well below that required for economic feasibility. Other swale sizes (bottom-widths) were also investigated, with similar results. The highest benefit-cost ratio obtained was 0.4.

Given the inability to identify a feasible alternative that meets the planning objectives and avoids the planning constraints, while addressing the technical, environmental, social and economic criteria as evaluated by the concepts of completeness, effectiveness, efficiency and acceptability, an alternative for Pecan Bayou cannot be identified as depicted in Table 6. Consequently, further detailed investigations for this study area will not be conducted.

Table 6

Economic Analysis of Structural Plans

($1000's, May 2000 prices and levels of development)

Alternative Bottom-width	Residual Damages	Flood Reduction	Insurance Subsidy	Annual Benefits	Annual Costs	Net Benefits	B/C Ratio
No Action	$ 735						
PB50	$ 729	$ 5.9		$ 5.9	$ 277.0	$ (271.1)	0.02
AS10	$ 647	$ 88.1		$ 88.1	$ 245.0	$ (157.4)	0.36
AS50	$ 631	$ 104.1	$ 0.1	$ 104.3	$ 436.0	$ (331.9)	0.24
AS100	$ 615	$ 120.1	$ 0.4	$ 120.6	$ 626.0	$ (505.5)	0.19

PB = Pecan Bayou AS = Adam Branch / Swale

Willis Creek

Based on the initial screening of nonstructural and structural alternatives, permanent evacuation and hydraulic channel improvement are two alternatives identified as warranting further study. A nonstructural plan was investigated through an array of alternatives but was not determined economically feasible in complying with planning objectives and constraints of this study. Presented below are the results of the additional detailed investigation of these alternatives.

Permanent Evacuation

Three different permanent evacuation scenarios were investigated on Willis Creek. The first called for the acquisition and removal of all (54) structures within the 50% ACE flood plain, the second was the acquisition and removal of all (144) structures within the 10% ACE flood plain, and the third was the acquisition and removal of all (274) structures within the 1% ACE flood plain. As shown in Table 7, the resultant benefit-to-cost ratios for the 10- and 1 percent zones were below unity and the ratio for the 50 percent zone had relatively minimal net benefits. There was no interest in pursuing lower level or partial protection for smaller number of structures without affecting "community cohesion". Basically stated, a permanent evacuation alternative cannot be recommended which removes only a portion of the affected structures while leaving a number of structures within the same flood plain in the study area. Therefore, permanent evacuation was eliminated from further consideration.

Table 7

Benefits of Nonstructural Alternatives on Willis Creek

($1000's, May 2000 prices and levels of development)

Flood Event	No.	Flood Free Value	Demolition Costs	Economic Costs	Annual Benefits	Annual Costs	Net Benefits	BCR	Financial Costs
0-50%	54	$ 4,387.6	$1,062.3	$ 5,450.0	$ 389.0	$ 384.0	$ 5	1.0	$1,527.0
0-10%	144	$ 9,186.7	$1,218.3	$ 10,405.0	$ 776.7	$1,072.0	($672)	0.7	$3,198.0
0-1%	274	$25,192.3	$8,661.4	$ 30,854.0	$1,033.0	$2,234.0	($1,201)	0.5	$5,661.4

Hydraulic Channel Improvement

As previously discussed, a hydraulic channel improvement was originally determined to be economically feasible on Willis Creek during the reconnaissance study. The primary objective of the hydraulic channel improvement was to contain flood flows within the banks of the creek and minimize losses. An update of the original analysis of the Willis Creek channel improvement alternative investigated a grass-lined channel beginning near Asbury Street and extending about 4,800-feet downstream of Austin Avenue. The total length of the improvement would be approximately 16,280-feet through the natural channel. The channel bottom width would be 45-feet with side slopes of 1V:3H. The initial center line for the improved channel would also be located such that the alignment would minimize adverse impacts to ecological resources as well as occupied land, i.e., back yards of those homes located adjacent to the creek through the use of one-sided excavation to fullest extent possible. This channel improvement would require a modification to the 4th street and 14th street bridges culverts, and utility relocations, primarily consist of water, sewer, gas, electric, telephone, and cable. Erosion protection would also be required along portions of the improved channel. Figure 7 displays the hydraulic channel improvement alternative.

Flood Damage Reduction.

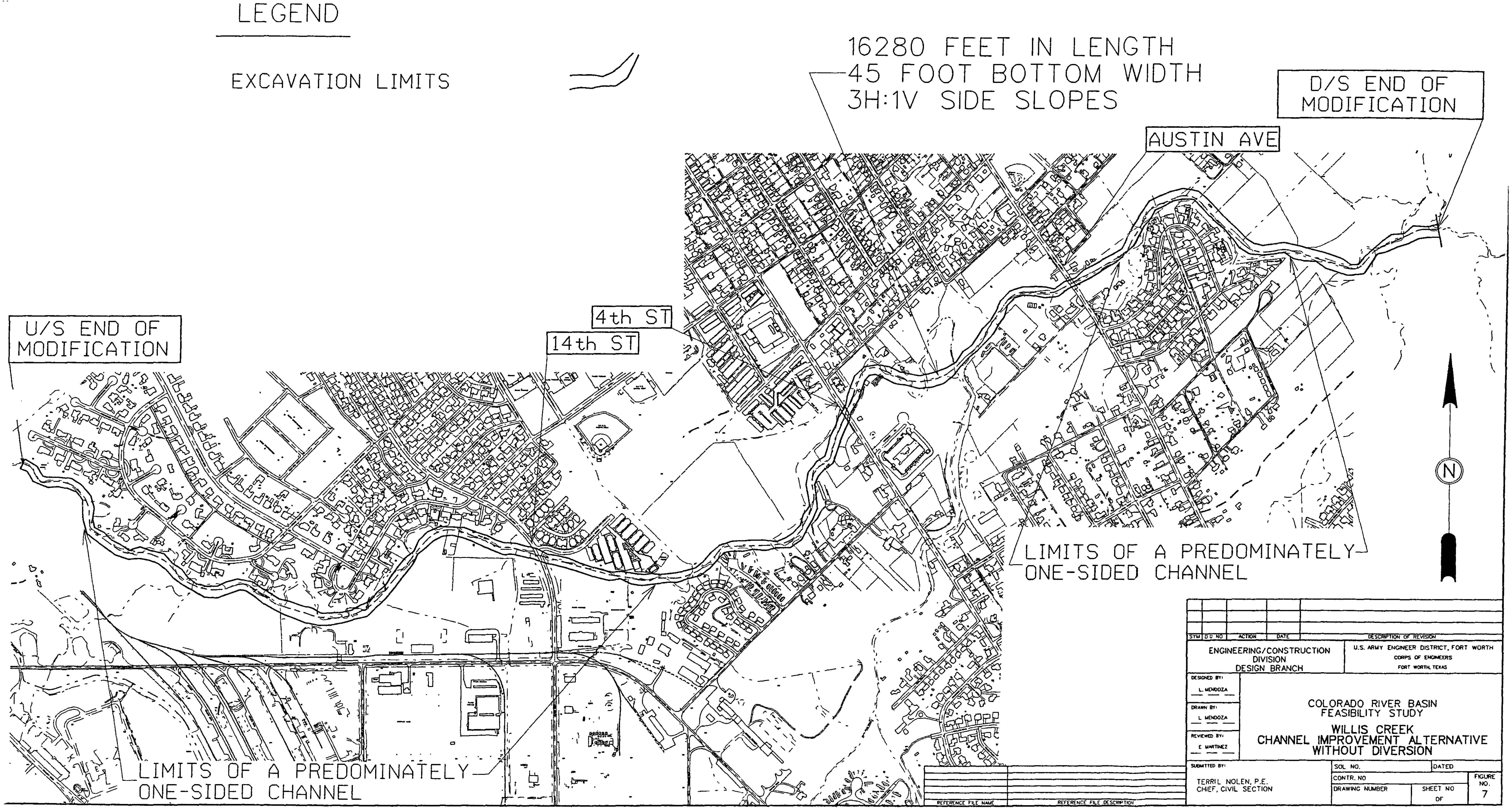
The channel was evaluated for bottom-widths of 10-, 25-, 45-, and 60-feet. Benefits quantified during these analyses were the reductions in damages to structures (residential and commercial) and their contents, and savings in flood insurance costs. These alternative plans would produce a damage reduction ranging from 47 percent to 97 percent based on planning level cost estimates. A summary of the residual damages and resulting benefits is presented in Table 8.

Table 8

Economic Benefits of Structural Plans for Willis Creek

($1000's, May 2000 prices and planning levels of development)

Alternatives	Residual Damages	Flood Benefits	Insurance Benefits	Total Benefits	% Damage Reduction
No Action	$ 956.7				
10-foot	$ 509.3	$ 447.3	$ 5.7	$ 453.0	47%
25-foot	$ 253.6	$ 703.0	$ 13.3	$ 716.3	75%
45-foot	$ 112.4	$ 844.2	$ 35.6	$ 879.9	92%
60-foot	$ 63.1	$ 893.5	$ 37.7	$ 931.1	97%



SYM	D O NO	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
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FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

REVIEWED BY: E. MARTINEZ

COLORADO RIVER BASIN
FEASIBILITY STUDY

WILLIS CREEK
CHANNEL IMPROVEMENT ALTERNATIVE
WITHOUT DIVERSION

SUBMITTED BY:
TERRIL NOLEN, P.E.
CHIEF, CIVIL SECTION

SOL NO.
DATED
CONTR. NO
DRAWING NUMBER
SHEET NO
OF
FIGURE NO. 7

CADD FILE NAME: cpecwip.dgn

IDENTIFICATION OF THE NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN

Knowing that a structural measure would address the stated planning objectives and constraints, the initial channel configuration was refined to identify one configuration that would maximize the net benefits to be determined as the NED plan. The identification of the NED plan will be accomplished by varying bottom widths and altering the alignment to avoid known or potential ecological and cultural resources as well as other physical constraints such as contaminated material, bedrock, etc. As depicted in Table 9, a planning level economic analysis was performed on the four bottom widths of 10-, 25-, 45- and 60-feet to determine the greatest net benefits.

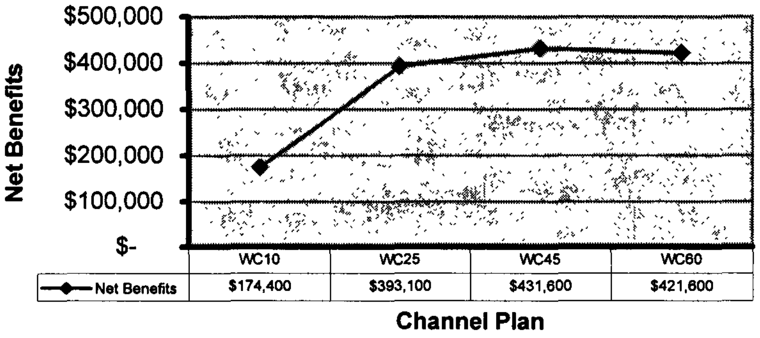
Table 9

Economic Analysis of Structural Plans For Willis Creek
($1000's, May 2000 planning prices and levels of development)

	10-foot	25-foot	45-foot	60-foot
Estimated First Cost	$3,765,600	$4,321,300	$5,978,700	$6,735,300
Construction Period (Months)	12	15	18	21
Investment Cost	$3,888,997	$4,499,271	$6,275,785	$7,127,892
Operation/Maintenance ($/Year)	$10,000	$12,500	$15,000	$17,500
Total Annual Charges	**$278,510**	**$323,146**	**$448,303**	**$509,635**
Total Annual Benefits	**$452,954**	**$716,276**	**$879,854**	**$931,200**
Net Benefits	$174,444	$393,130	$431,551	$421,565
Benefit-to-Cost Ratio	**1.6**	**2.2**	**2.0**	**1.8**

The 45-bottom width channel produces the greatest net benefits of $431,551 with total and annual projects costs of $5.9 million and $448,300, respectively. The plan would reduce expected annual damages by 92 percent; eliminate all the damages in the 11 percent ACE event and 90 percent of the damages caused by the 1-percent flood event. The resultant plan has a benefit-cost ratio of 2.0 to 1.0 and net benefits (annual benefits in excess of annual costs) of about $431,600. The optimization curve presented in Table 10 depicts the net benefits associated with the channel and confirms the 45-foot channel as the selected alternative. Table 11 shows the number of structures in each flood zone following plan implementation and the number of structures saved in each flood zone following project implementation.

Table 10
Willis Creek
Channel Optimization



Revised August 2002

Table 11

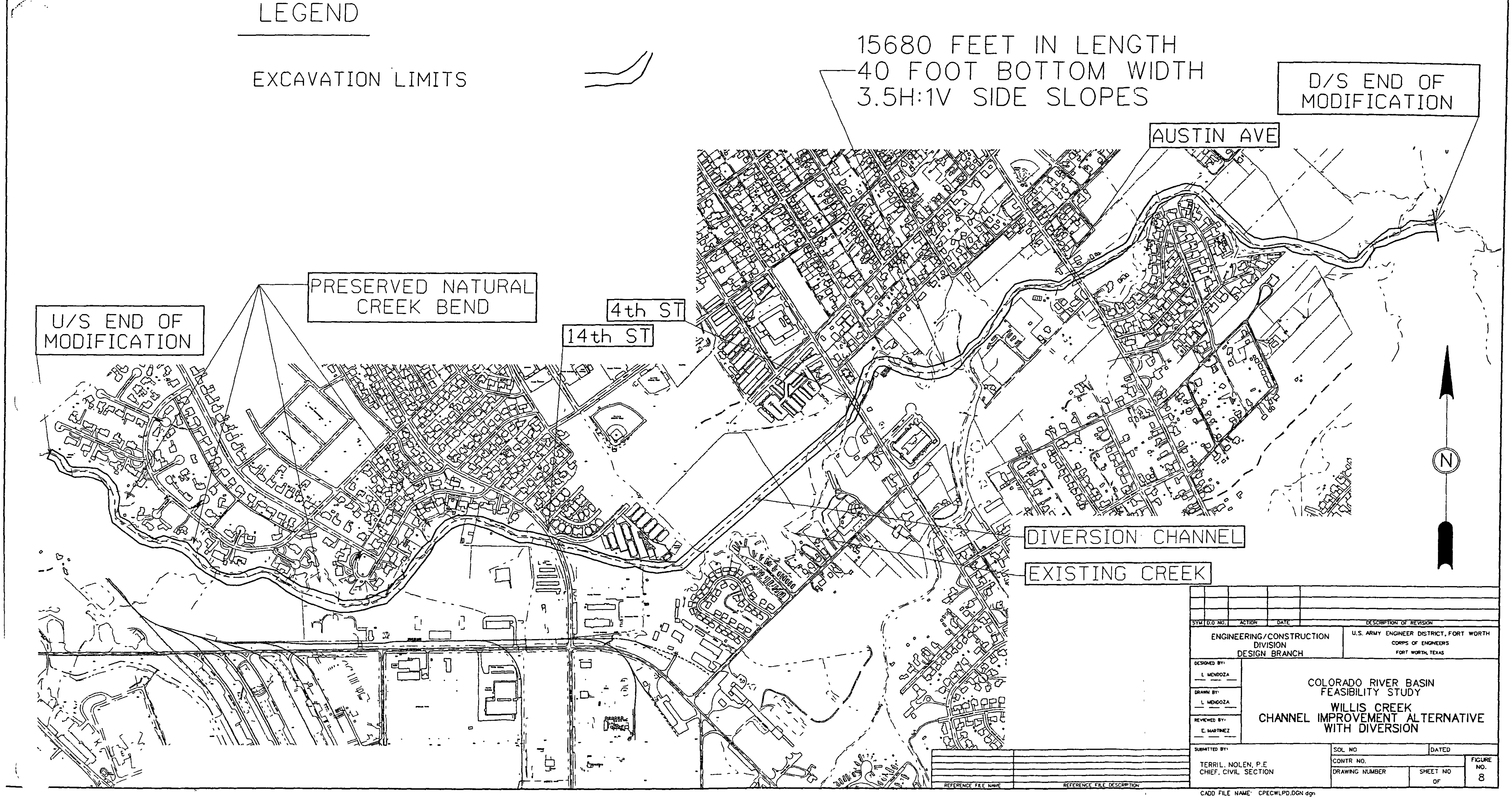
Flood Zone Location of Structures

With and Without Project Summary

Alternative	10%	4%	2%	1%	0.2%
Existing	144	214	255	274	322
Number of Structures Remaining by Flood Event					
Willis A 10	59	122	201	235	306
Willis B 25	0	39	126	183	284
Willis C 45	0	6	12	30	240
Willis D 60	0	6	10	16	145
Total Structures Saved from Flooding					
Willis A 10	85	92	54	39	16
Willis B 25	144	175	129	91	38
Willis C 45	144	208	243	244	82
Willis D 60	144	208	245	258	177

Optimization

Further refinement was investigated to reduce adverse ecological impacts resulting from a hydraulic channel improvement. Although the channel centerline and alignment were set to minimize adverse ecological resources, additional resources could be avoided via a diversion channel. As shown in Figure 8, the diversion channel would begin about 1,200 feet downstream of 14th Street extending downstream a distance of 2,000 feet, and reentering Willis Creek about 500-feet upstream of 4th Street. The diversion channel is described as a grass-lined, trapezoidal channel having side slopes of 1V:3H and a 45-foot bottom width (given the 45-foot bottom width channel is proven to be the most efficient; no other bottom width for the diversion channel was investigated in detail). The effect of the diversion would be the avoidance of adverse impacts to the high quality riparian corridor in the area in question, as well as reducing environmental mitigation costs. The hydraulic channel improvement alternative up- and downstream of the diversion channel would remain the same. Table 12 displays a summary of the economic analysis of the hydraulic channel improvement alternative with the diversion for Willis Creek.



SYM	D.O NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

COLORADO RIVER BASIN
FEASIBILITY STUDY

WILLIS CREEK
CHANNEL IMPROVEMENT ALTERNATIVE WITH DIVERSION

SUBMITTED BY:
TERRIL. NOLEN, P.E
CHIEF, CIVIL SECTION

SOL NO
DATED
CONTR NO.
DRAWING NUMBER
SHEET NO
OF
FIGURE NO. 8

REFERENCE FILE NAME
REFERENCE FILE DESCRIPTION

CADD FILE NAME: CPECWLPD.DGN dgn

Table 12

Planning Level Economic Analysis of Structural Plans For Willis Creek with Diversion

($1000's, May 2000 prices and levels of development)

	10-foot	25-foot	45-foot	60-foot	45-foot Diversion
Estimated First Cost	$3,765,600	$4,321,300	$5,978,700	$6,735,300	$5,942,400
Construction Period (Months)	12	15	18	21	18
Investment Cost	$3,888,997	$4,499,271	$6,275,785	$7,127,892	$6,237,681
Operation/Maintenance ($/Year)	$10,000	$12,500	$15,000	$17,500	$17,500
Total Annual Charges	**$278,510**	**$323,146**	**$448,303**	**$509,635**	**$445,672**
Total Annual Benefits	**$452,954**	**$716,276**	**$879,854**	**$931,200**	**$879,854**
Net Benefits	$174,444	$393,130	$431,551	$421,565	$434,182
Benefit-to-Cost Ratio	**1.6**	**2.2**	**2.0**	**1.8**	**2.0**

Based on the planning level economic analysis in Table 12, the 45-ft bottom width alternative with diversion provides the greatest net benefits comparatively among any alternatives evaluated in detail.

When updated with current costs and pricing data of May 2001 through an MCASES cost estimate, the total and annual project cost of the recommended plan with diversion channel is estimated at $8,270,190 and $574,000, respectively as indicated in Table 13. Significant Estimated First Costs were increased due to higher real estate costs when updated with current costs respectively. The resultant BCR is 1.55 to 1.0 with about $313,600 in net benefits. Table 14 presents the overall project performance accounting for risk and uncertainty. As shown, there is a 87 percent probability that the project would contain the 25-year or 4 percent ACE event. However, it should be recognized that the project is expected to *reduce* overall damages.

Table 13

Economic Analysis of Alternative with Diversion For Willis Creek

($1000's, May 2001 prices and levels of development)

	WC45 w/Diversion
Estimated First Cost	$8,270,190
Construction Period (Months)	18
Investment Cost	$8,650,121
Operation/Maintenance ($/Year)	$15,600
Total Annual Charges	**$574,000**
Total Annual Benefits	$887,600
Net Benefit	**$313,600**
Benefit-to-Cost Ratio	1.55

Table 14
Project Performance of Willis Creek Recommended Plan

	Expected Annual Target Stage Exceedence Probability		Long Term Risk (Years)			Conditional Non-Exceedence Probability by Event					
Target Stage	Median	Expected	10	25	50	10%	4%	2%	1%	.4%	.2%
1358	.007	0.017	.158	.349	.576	0.985	0.847	0.698	0.594	0.458	0.370

The following sections describe other affects of the hydraulic channel improvement.

Ecological Resources

The effects to ecological resources were quantified during the analysis of the various bottom widths investigated. The recommended 45-foot bottom width channel with the diversion has less impact on high-quality riparian habitat than the other structural alternatives evaluated. Table 15 displays a summary of the habitat and acres affected.

Table 15
Habitat and Area Effected

	Bottom Width				
	10-Feet	25-Feet	45-Feet	60-Feet	45-Feet w/ Diversion
Riparian	27 acres	33.8 acres	37.7 acres	39.6 acres	15.9 acres
Old Field	7.7 acres	9.1 acres	9.9 acres	13.8 acres	31.7 acres
Stream	16,554 feet	16,554 feet	16,554 feet	16,554 feet	13,336 feet

As seen Table 15, the adverse effects to the high-quality riparian habitat is maximized with the 45-foot bottom width channel improvement given the proximity of the habitat to the top of the channel bank. Additional adverse effects from a larger channel improvement are experienced only to the relatively lower-quality old-field habitat. The trade-off between reduced adverse effects to the riparian habitat at the expense of additional impacts to the old-field habitat is acceptable.

Threatened and Endangered Species

Threatened or endangered species were not identified in the study area or in the layout of the recommended plan. Therefore, they have no adverse bearing on the plan.

Cultural Resources

The hydraulic channel improvement alternative will not have any affect on any historic structures. The area, does however, exhibit significant alluvial deposition and the potential for archaeological sites to be buried within this alluvium is extremely high. This potential exists wherever the channel may be placed. A cultural resources survey and backhoe trench subsurface testing of the alluvial deposits for possibly buried archaeological sites will be necessary during the next phase of project development. If significant archaeological sites are encountered during this survey and subsurface testing, then these sites will need to be avoided or mitigated through data recovery.

Hazardous, Toxic, and Radioactive Wastes

The initial site assessment, including reviews of the regulatory records and databases, aerial photographs, and interviews indicate the lack of a presence of apparent HTRW releases or CERCLIS sites in or near the study area. The one area of concern is located south of the creek, and west of 14thStreet. This site is a Formerly Used Defense Site (Camp Bowie), and was used as a potential uncontrolled dumping site. An investigation of the site concluded that the area contained solid municipal waste. The investigation did not identify any hazardous material. While the initial indication is that the channel improvement alternative is not likely to disturb or impact the buried municipal waste, additional investigations may be required to determine the exact location (boundary) of the known waste. However, since this was a Federal facility, if any hazardous or contaminated materials are found, the responsibility for cleanup will fall to the Federal Government.

NATIONAL ECONOMIC DEVELOPMENT PLAN

The National Economic Development (NED) plan is that alternative which addresses the planning objectives and constraints, and has the greatest amount of net benefits, consistent with protecting the Nation's environment. As described n page 40, the NED plan was initially identified as the alternative with a 45-foot bottom width with the diversion.

SELECTION OF THE RECOMMENDED PLAN

The recommended plan is supported by the local sponsor, and is identified as the recommended plan.

As part of the detailed engineering and design on the initially identified NED plan, the city of Brownwood requested a variation of the bank slopes from 1 vertical to 3.0 horizontal to 1 vertical to 3.5 horizontal for ease of maintenance. Review of this request revealed that this could easily be accomplished without having any impacts to the cost and output of the NED plan by narrowing the bottom width from 45 feet to 40 feet. A review of the costs, hydraulic capacity, real estate requirements, project benefits and net benefits determined that the differences would be negligible.

This section provides further details on the Recommended (NED) Plan, as determined in the preceding chapters of this report. Detailed cost estimates were developed with May 2001 price levels and is presented as categorized in the various MCACES accounts. Federal and non-Federal cost apportionment responsibilities are also presented.

DESCRIPTION

As described above, the Recommended (NED) Plan is a flood damage reduction project consisting of 15,680 feet of hydraulic channel improvement on Willis Creek within the city of Brownwood. The improvement consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. The upper segment of the improvement begins near Asbury Street, and extends approximately 6,400 feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel will be excavated across an open field, reconnecting to Willis Creek about 2,000 feet downstream (approximately 500 feet upstream of 4th Street). The improved channel continues downstream, approximately 7,880 ft to the terminus of the plan approximately 1600 feet east of Quail Creek Court. The proposed improvement will primarily follow the existing creek alignment with the exception of several creek bends that will be bypassed and the 2000-foot diversion channel between 14th Street Bridge and 4th Street Bridge. The bypassed creek bends will be preserved within the channel with base flows to provide for deeper pools and ripples to act as wetlands and provide wildlife habitat. Approximately 96 acres of reforestation will be undertaken to mitigate habitat removed by the channel excavation. The improvement will also require box culvert modifications to the 14th Street and 4th Street bridges, side slope modifications at the Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection.

MAJOR PROJECT FEATURES

Structures

The City will be responsible for removing and/or relocating all miscellaneous structures, small sheds, and detached buildings that are within the limits of improvement prior to the award of the Willis Creek Project.

Roads

No roads will be relocated, however modifications to the box culverts at 4th Street and 14th Street will require road and culvert improvements during construction. Austin Avenue road and bridge will not be impacted.

Utilities

Various utility lines will be impacted throughout the improvement along Willis Creek. Approximately 565-feet of various storm drains (reinforced concrete and galvanized pipe), 1350-feet of sanitary sewer, 115-feet of gas lines, and 415-feet of water lines will need to be extended and/or relocated.

Modifications

In order to minimize constriction of flow, the existing box culverts at 4th street and 14th street will need to be enlarged. This consists of adding 3 additional 10' wide x 8' deep box culverts to the existing culverts at 4th street and removing the existing culverts at 14th street and adding an 8 barrel 10' x 10' box culvert. No structural modifications are required at Austin Avenue bridge, however some side slope modifications will be required for the approach transitions. Riprap will be placed at the bridge approaches for erosion protection.

Disposal Areas

The city of Brownwood has established a location for the excess excavated and waste materials. The primary site for the disposal of materials from Willis Creek is the local city of Brownwood landfill located approximately 0.75 miles southwest of the intersection of F.M. 2126 and F.M. 45. This 33 acre disposal site will accommodate the estimated 260,000 cubic yards of overburden material which has been initially determined free of any HTRW concerns. The haul distance from project site to the landfill will vary from 3-5 miles depending on the specific staging areas. Disposal of excavated materials to this site does not pose any adverse cultural, environmental, or HTRW concerns. As suggested by the U.S. Fish and Wildlife Coordination Act Report, the City and the Corps will investigate the potential of using some debris material from brush and tree clearing on-site within the mitigation areas to construct habitat features, such as nest boxes, brush piles, stumps, logs, and large boulders, instead of removing the material to an off-site disposal area.

Construction Access and Staging Areas

Temporary construction access and staging areas for the construction contractor will consist of three locations along the channel improvement to move in conjunction with the construction progress. The upstream segment will have 1.9-acre strip for temporary construction access from Highway 377 to the edge of Stonebrook Court and a 0.8-acre temporary staging area. The mid-channel segment will be located on the west side of the 4th Street bridge and have a 0.6 acre strip for temporary road easement, a 0.6 acre temporary work area easement for staging purposes. The downstream staging area is located approximately 800 ft from the end of the channel improvement and will have a 0.5-acre strip for temporary road easement and 1.6 acres for temporary work staging easement. Temporary easement access to this staging area will tie into the corner of Wood Ave and Cottage Street.

Real Estate Requirements

The project lands lies within the city limits of Brownwood. The Recommended Plan will require a maximum of 170.6 acres of Lands, Easements, Right of Ways, Relocations, and Disposal (LERRDs) areas to be obtained. This includes 60 acres for channel improvement easement, 1.9 acres for temporary work area easements, 4.1 acres for road access easement, and 104.6 acres for environmental mitigation. Implementation of this proposed project does not necessitate the relocation of any residences.

Recreational Features

The recommended plan is a hydraulic channel improvement project for the purpose of flood damage reduction project and the city of Brownwood did not have interest in pursuing any recreational features. Therefore, this study does not contain any recreational benefits, however future considerations by the city could offer walking trails through the mitigation areas once the site is established and there are no adverse impacts to the mitigation areas.

IMPACTS OF THE RECOMMENDED PLAN

Flood Damage Reduction

USACE policy regarding avoidance of any potentially detrimental impacts, both upstream and downstream from the identified project reach, was followed during this study. Pecan Bayou, which has a contributing drainage area of approximately 1736 square miles, in comparison to the Willis Creek watershed of approximate 28 square miles, thoroughly dominates the flooding potential at and below the mouth of Willis Creek. The Recommended Plan will serve to consistently lower and/or maintain projected water surface elevations along the entirety of the developed reaches of Willis Creek and would reduce annual flood damages by 92%. The Plan would eliminate all damages within the 10 percent (10 year) floodplain and almost 60 percent damages within the 1 percent (100 year) floodplain. Figures 9A, 9B, & 9C illustrate the Recommended Plan with and without project conditions for the 1 percent floodplain.

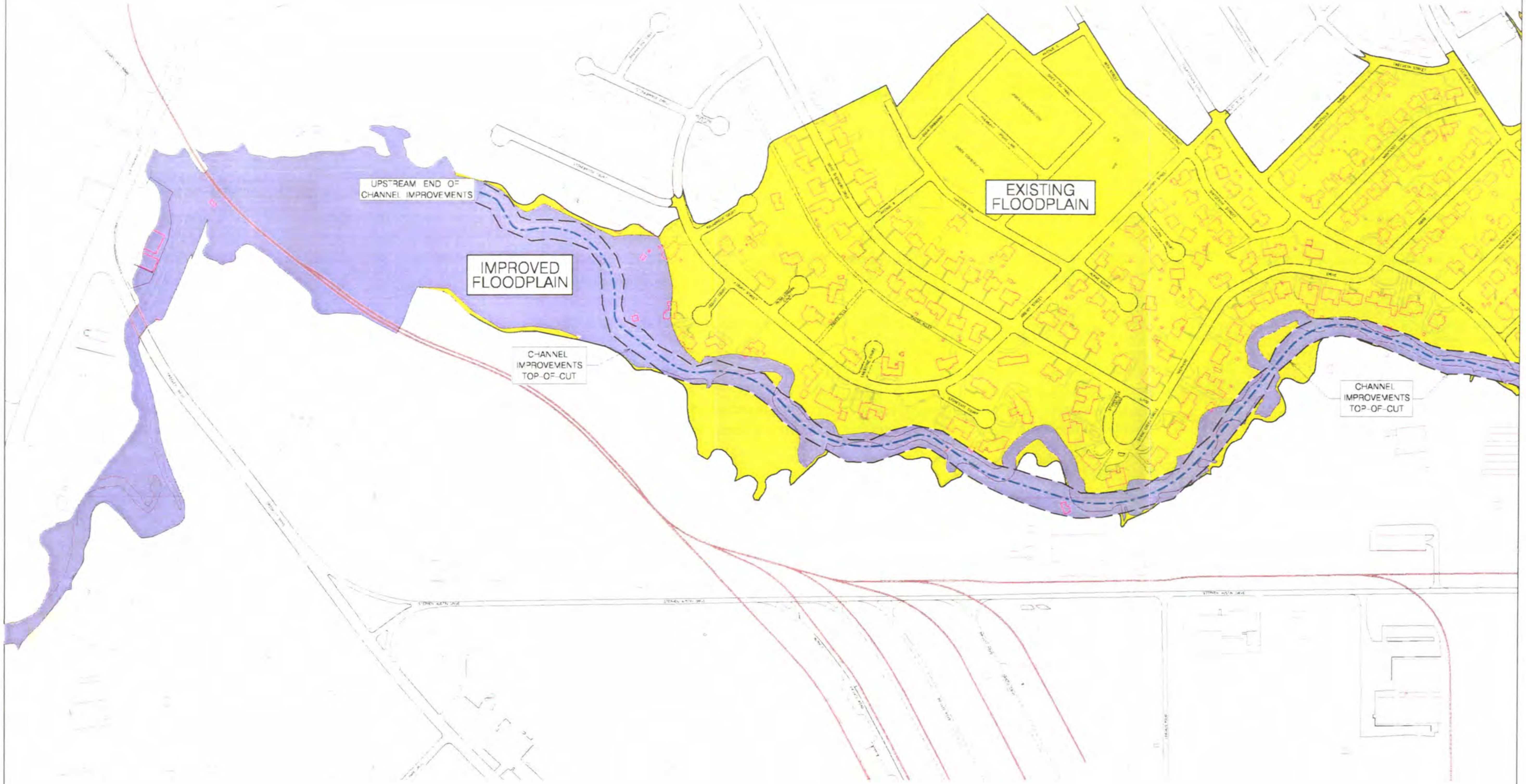
Site-specific impacts, such as those related to occasional sedimentation and/or degradation of the channel bed and banks at the interfaces between the modified and unmodified reaches of the project will be improved upon through application of scour-prevention media (rip-rap, geotextiles, etc.) and via a defined maintenance program. Specific details and locations of these project features will be carefully identified and configured during the subsequent Plans and Specifications Phase.

Hazardous, Toxic, and Radioactive Wastes

Previous investigations channel site indicates that the current alignment of the Recommended Plan will not encounter any hazardous, toxic, or radiological waste. As such, no additional investigations will be required. However, should the final alignment of the channel shift to the south towards the former Camp Bowie landfill area, additional investigations will be required to determine the exact extent of the landfill.

Land Use

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit an Floodplain Management Plan (FPMP). Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be further adversely impacted as a result of implementing the recommended plan.



SCALE: 1" = 450'

PREPARED BY
L.ESKEW

REVIEWED BY
C. LOFTIN

SUBMITTED BY /DATE
16JULY01

WILLIS CREEK CHANNEL IMPROVEMENTS

100-YEAR FLOODPLAIN – WITH AND WITHOUT PROJECT

SHEET NO.

SEQ. NO.
9A

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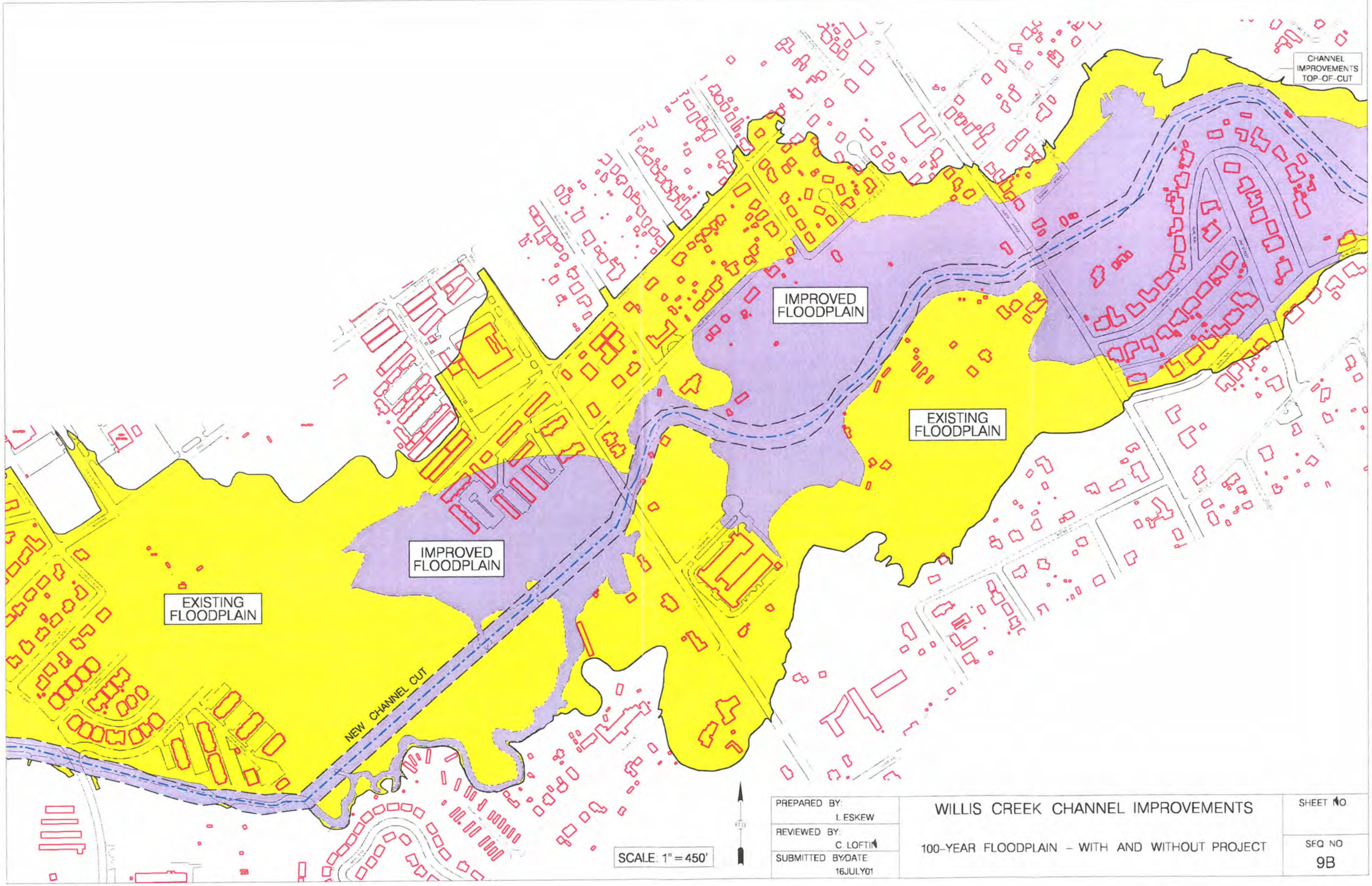

PREPARED BY:
L ESKEW

REVIEWED BY:
C. LOFTIN

SUBMITTED BY/DATE:
16JULY01

WILLIS CREEK CHANNEL IMPROVEMENTS

100-YEAR FLOODPLAIN - WITH AND WITHOUT PROJECT

SHEET NO.

SEQ NO
9B

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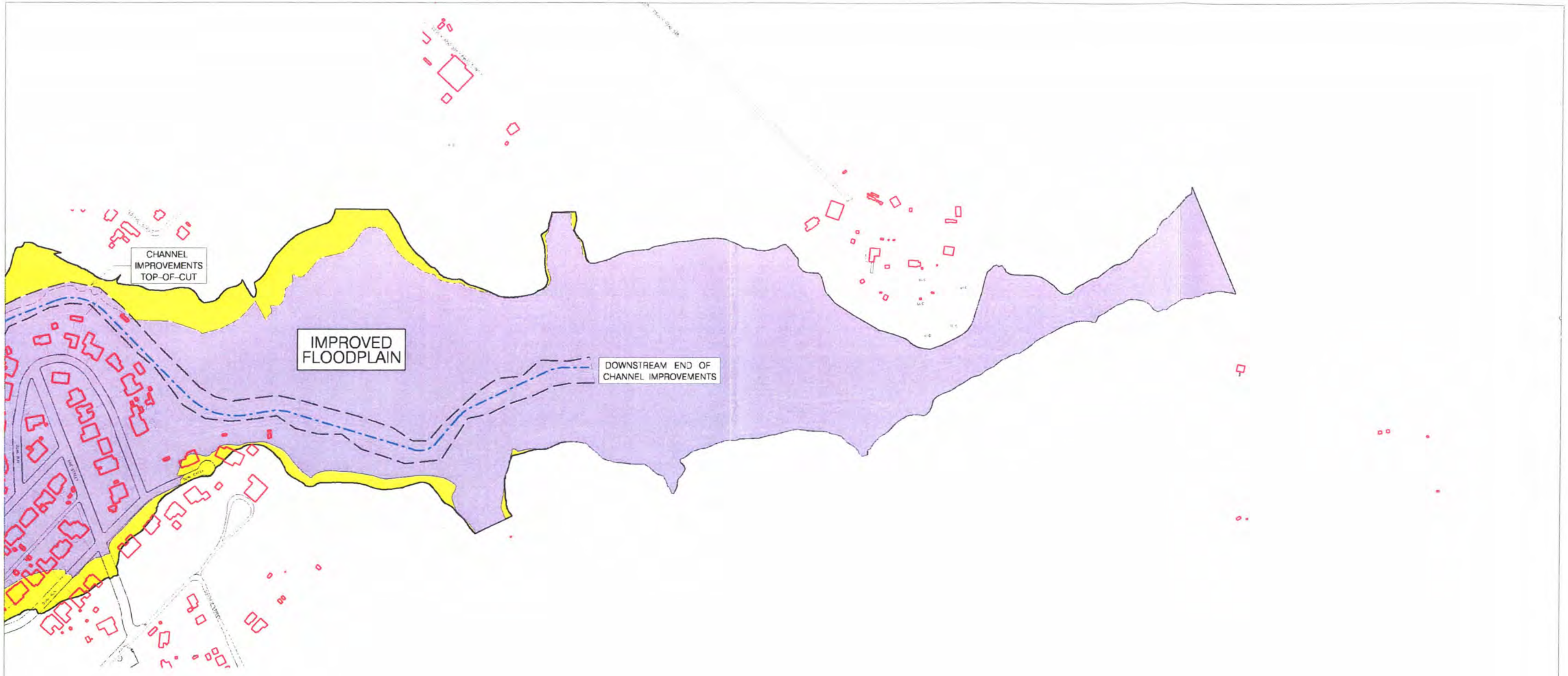

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PREPARED BY: L.ESKEW	WILLIS CREEK CHANNEL IMPROVEMENTS	SHEET NO.
PREPARED BY: C. LOFTIN	100-YEAR FLOODPLAIN - WITH AND WITHOUT PROJECT	SEQ NO 9C
PREPARED BY: 16JULY01		

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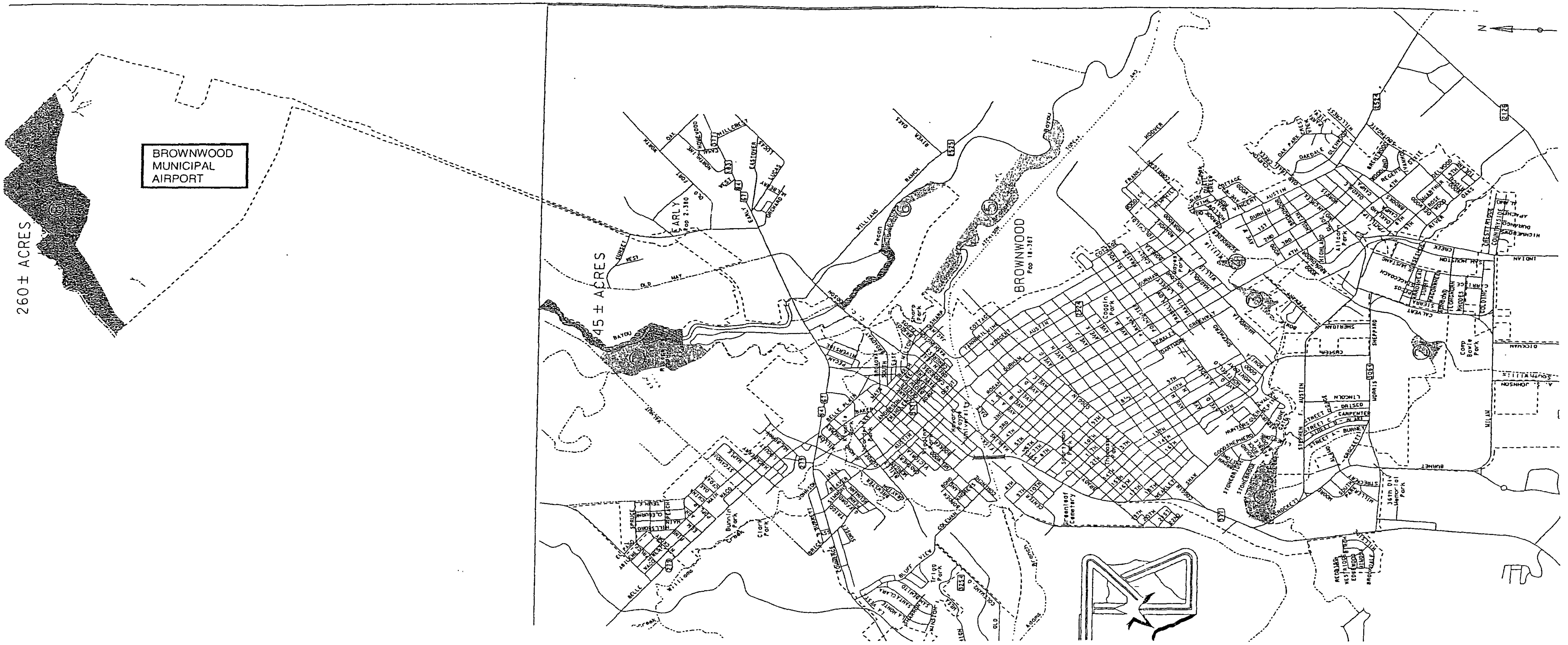


Figure 10

IDENTIFIED MITIGATION SITES

WILLIS CREEK CHANNEL IMPROVEMENT
BROWNWOOD, TEXAS

Air Quality

Construction activity associated with the implementation of the recommended would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the recommended plan would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

Water Quality

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem.

Adverse impacts to water quality would be minimized through the development and implementation of a National Pollution and Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan (SWPPP) that require provisions for corrective and implementable measures to prevent pollutants from entering Willis Creek during a storm event that would occur during and after construction activities. This requirement is for project sites greater than 5 acres, including all temporary access roads, trailer sites, storage areas, and any other disturbed area associated with the project. The contractor would be required to complete a Notice of Intent (NOI) for Storm Water Discharges as required for an NPDES General Permit administered by the Environmental Protection Agency (EPA). The Contractor would also develop a detailed SWPPP within the guidelines of the COE's basic SWPPP and will provide drawings to accompany the SWPPP showing the locations of all stormwater controls. Stormwater controls entail both methods for temporary and permanent stabilization.

Temporary Measures To Minimize Short-term Adverse Impacts to Water Quality

Temporary stabilization activities would occur for all unpaved, graded and disturbed portions of the site when construction activities cease for 21 days or more and there is no requirement for permanent turfing. Temporary stabilization include structural and nonstructural measures. A nonstructural method for temporary stabilization would be to till the soil around Willis Creek to a depth of four inches, spread native prairie hay such as broomsedge, bluestem, little bluestem, big bluestem, switchgrass, and Indian grass, at a rate of 4000 pounds per acre, and anchor the mulch into place using a mulch anchoring machine equivalent to a disk harrow with cupped disks removed and replaced with straight rolling coulters spaced not more than eight inches apart. Structural stormwater controls would be used during temporary stabilization to prevent soil erosion where construction produces the potential for significant erosion damage, particularly where there is significant slope and at the boundaries of the project's unpaved and disturbed land. Some of the typical temporary structural stormwater controls that would be used to minimize sediment runoff include silt fences, staked hay bales, diversion dikes, excavated sediment traps, pipe slope drains, rock berm or check dams, log check dams, rock check dam, and sand bag berms. In feasibility, the level of detail of study detail makes it impractical to state specifically what measures would be used and where the stormwater controls would be placed, the following are the specific conditions under which each measure could be utilized:

Silt Fence – Silt fences shall be used for drainage areas of 1 acre or less with velocities of 0.5 FPS or less. The silt fences would not be constructed in tributaries or swales that lead into Willis Creek. The silt fences would be used primarily for perimeter control of overland flow to prevent sheet and rill erosion. Sediment would be removed from the silt fence when it accumulates to one-third the height of the fence. The silt fences would be securely fastened to each support post or to the backing, which is in turn attached to a fence post. See Figure 11.

Staked Hay Bales – Staked hay bales would be used for drainage areas of 1 acre or less with velocities of 0.5 FPS. The bales would not be used in tributaries or swales that lead into Willis Creek. The hay bales would be used primarily for perimeter control of overland flow to prevent sheet and rill erosion. The hay bales would be used where the effectiveness is required for less than 3 months, or the bales would be replaced every three months. Hay bales would be placed end to end with no caps between the bales. The accumulated sediment would be removed and disposed when it reaches a depth of 6". See Figure 12.

Diversion Dikes – Diversion dikes would be used to divert storm flows of 1 foot in depth or less, from Willis Creek. The side slopes of the diversion dikes would be 3:1 or flatter and the minimum width of the embankment at the crown would be 2 feet. Dike height would be a minimum of one foot greater than the flow depth for the 10-year event. Diversion dikes would be placed parallel to existing contours for perimeter control by diverting run-on water away from the disturbed area. See Figure 13.

Excavated Sediment Trap - An excavated sediment trap would be used in small drainage areas around Willis Creek of less than 1 acre, where overflow capacity is needed and in areas of heavy flow, 0.5 CFS or greater. The drainage area would be fairly flat with slopes of 5% or less. Washed gravel (3-5 inches in diameter) would be used to a depth of at least 1 foot. The recommended volume of sediment trap is 35 cubic yard per acre disturbed. Sediment would be removed from the trap when it accumulates to half the height of the filler stone. Weep holes would be filled with grout prior to backfilling of storage. See Figure 14.

Pipe Slope Drain – A pipe slope drain would be recommended for drainage areas around Willis Creek up to 10 acres. The pipe inlet and outlet would be stabilized. A flared end section would be used at the entrance of the pipe and soil around the pipe fully compacted. The outlet would enter into a 12inch thick bed of riprap. Diversion dike height on the drain would be a minimum of one foot greater than the flow depth for the 10-year event. See Figure 15.

Rock Berm or Check Dam – Check dams would be installed in steeply sloped swales or in swales sloping into Willis Creek where adequate vegetation cannot be established (not streams). Open graded rock, 4-8 inches in diameter would be used in the check dams. The dams would be secured with a woven wire sheathing having maximum 1 inch opening and minimum wire diameter of 20 gauge. Check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it accumulates to one-third of the height of the berm. See Figure 16.

Log Check Dam – Log check dams would be installed in steeply sloped swales, or in swales sloping into Willis Creek where adequate vegetation cannot be established (not streams). The logs used would be from 6 to 8 inches in diameter. Log check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it reaches a height of one half the original dam height. See Figure 17.

Rock Check Dam – Rock check dams would be installed around Willis Creek in drainage areas of 2 acres or less. Rock check dams would be constructed with 5 to 15 inch diameter stone. The maximum height of the rock check dam would be no greater than 3 feet and the center of the dam would be 6 inches lower than the outer edges. For added stability, the dam would be keyed into the surrounding soil approximately 6 inches deep. Filter cloth may be added under the stone to provide a stable foundation and facilitate removal of the dam. Rock check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it reaches a height of one half the original dam height. See Figure 18.

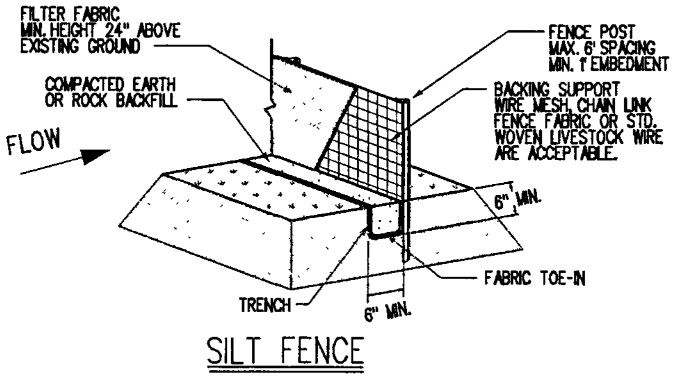
Sand Bag Berm – Sand bag berms would be used around Willis Creek, when the contributing drainage area is greater than 5 acres. The sand bags would be constructed from polyethylene, polyamide or cotton burlap woven fabric, have a minimum weight of four ounces per square yard, a mullen burst strength exceeding 300 PSI and ultraviolet stability exceeding 70 percent. Sand bags would be 24 to 30 inches in length, 16 to 18 inches in width and 6 to 8 inches in thickness. The sand bags would be filled with coarse grade sand, free from deterous material, and shall pass through a No 10 sieve. The minimum weight of the bag would no less than 40 lbs. See Figure 19.

The construction contractor would be able to select from these temporary measures for sediment control according to the appropriate existing conditions. The final selection of controls would have to be approved by a Corps of Engineers Contracting Officer. Many of the aforementioned stormwater controls are temporary and would be removed after final site stabilization is completed. Some of the temporary stormwater measures; however, would remain in place as permanent measures to control erosion, create additional wildlife habitat, and improve water quality.

Permanent Measures to Minimize Long-term Adverse Impacts to Water Quality

Permanent site stabilization would occur at the Willis Creek project site when construction activities permanently cease. Several of the measures previously described for temporary stabilization would applicable for permanent stabilization. Of the methods previously described for temporary stabilization, those measures that utilize natural materials such as the log and rock check dams would remain in place permanently. The log and rock check dams would provide permanent stabilization in areas where there is high erosion potential. The stabilization and reduction of soil erosion that would occur in the bank areas where these measures have been installed would eventually allow riparian vegetation to become established, create additional wildlife habitat and provide water quality benefits by filtering runoff water that flows into Willis Creek during storm events. In addition to the permanent stabilization measures previously identified, turfing work would be done from 1 April to 1 June. Live sod would be placed on all disturbed and unpaved areas. If available living sod containing native vegetation would be used. The areas to be sodded would be excavated to a sufficient depth so that the top of the sod when set in place would be about ½ inch below the surrounding soil at the outer edges of the solid sodded area. Sod would be immediately pressed firmly into contact with the sod bed by hand tamping. Screened soil of good quality would be used to fill all cracks. Sod would be watered and fertilized at an approved rate and for a duration necessary to ensure permanent survival. The native sod would serve habitat for the native wildlife species by providing food, cover, and nesting material. The sod would act as a filter to improve the water quality of Willis Creek and runoff water during storm events.

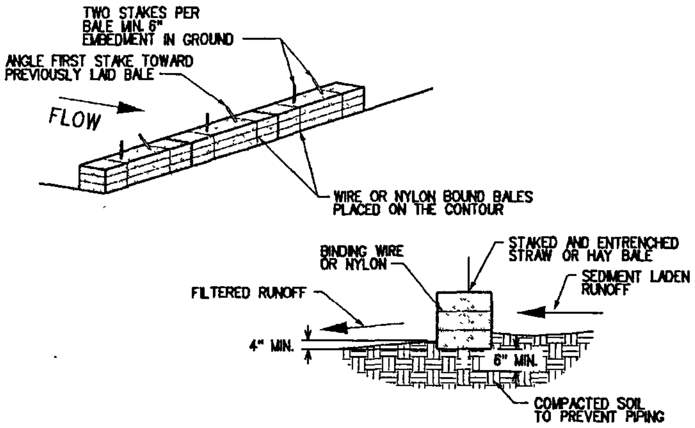
Also a non-maintenance herbaceous riparian corridor would be maintained a minimum of 5 ft from the edge of the base flow channel. Non-woody native vegetation, such as sedges, grasses, and rushes, would be allowed to establish in the zone next to the base flow channel. In addition, a forested riparian corridor containing native species, planted according to the recommendations listed in the Fish and Wildlife Coordination Act Report (Appendix F) would be established along the top of bank where it has been adversely impacted by the one-sided excavation. The forested riparian area would provide positive aesthetic benefits, sediment stabilization capability, and shading to cool the water in Willis Creek.



NOTES:

1. SILT FENCES SHALL ONLY BE USED FOR DRAINAGE AREAS OF 1 ACRE OR LESS WITH VELOCITIES OF 0.5 CFS OR LESS.
2. SILT FENCES SHALL NOT BE CONSTRUCTED IN STREAMS OR SWALES.
3. SILT FENCES SHALL BE USED FOR PERIMETER CONTROL OF OVERLAND FLOW TO PREVENT SHEET AND RILL EROSION.
4. CONTRACTOR SHALL REMOVE AND DISPOSE OF SEDIMENT WHEN IT ACCUMULATES TO ONE-THIRD THE HEIGHT OF THE FENCE.
5. SILT FENCE SHALL BE SECURELY FASTENED TO EACH SUPPORT POST OR TO WOVEN WIRE, WHICH IS IN TURN ATTACHED TO THE FENCE POST.

Figure 11. An illustration of a silt fence stormwater control structure.

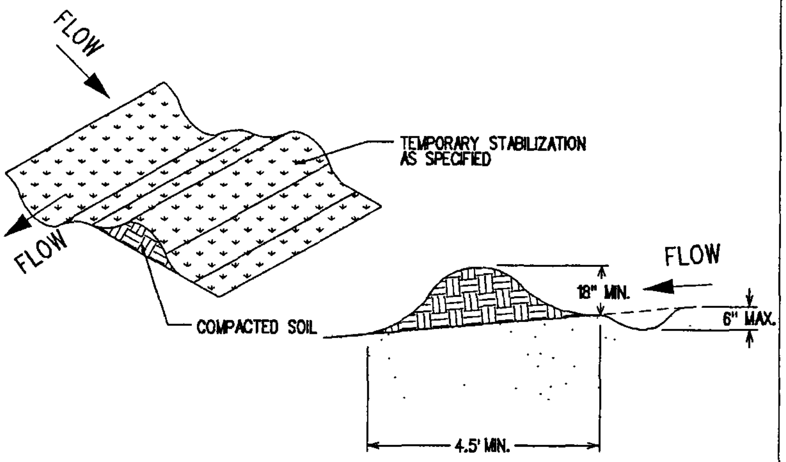


STAKED HAY BALES

NOTES:

1. BALES SHALL ONLY BE USED FOR DRAINAGE AREAS OF 1 ACRE OR LESS WITH VELOCITIES OF 0.5 CFS OR LESS.
2. BALES SHALL NOT BE CONSTRUCTED IN STREAMS OR SWALES.
3. BALES SHALL BE USED FOR PERIMETER CONTROL OF OVERLAND FLOW TO PREVENT SHEET AND RILL EROSION.
4. BALES SHALL ONLY BE USED WHERE THE EFFECTIVENESS IS REQUIRED FOR LESS THAN 3 MONTHS.
5. BALES SHALL BE PLACED END TO END WITH NO GAPS BETWEEN THE BALES.
6. THE CONTRACTOR SHALL REMOVE AND DISPOSE OF SEDIMENT WHEN IT ACCUMULATES TO A DEPTH OF 6".

Figure 12. An illustration of a staked hay bale stormwater control structure.

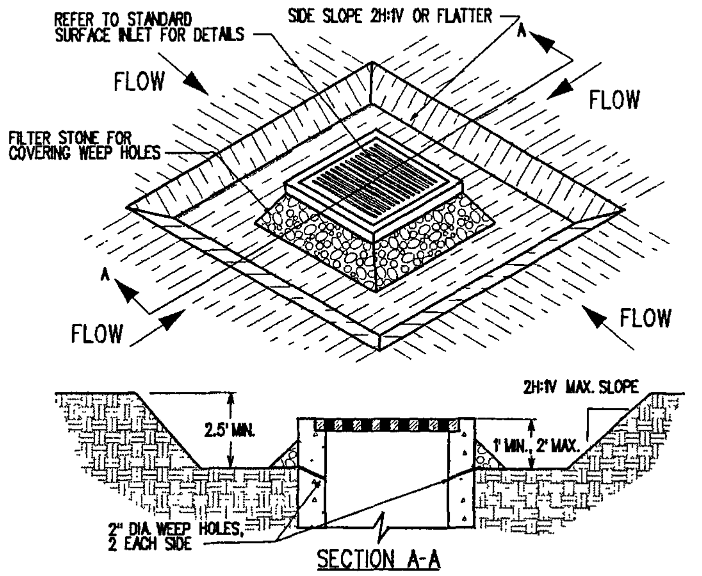


DIVERSION DIKE

NOTES:

1. SIDE SLOPES OF THE DIVERSION DIKE SHALL BE 3:1 OR FLATTER.
2. MINIMUM WIDTH OF THE EMBANKMENT AT THE TOP SHALL BE 2 FEET.
3. DIKES SHOULD ONLY BE USED TO DIVERT STORM FLOWS OF 1 FOOT IN DEPTH, OR LESS.
4. DIVERSION DIKES SHALL BE PLACED PARALLEL TO EXISTING CONTOURS FOR PERIMETER CONTROL BY DIVERTING RUN-ON WATER AWAY FROM THE DISTURBED AREA.
5. DIKE HEIGHT SHALL BE A MINIMUM OF ONE FOOT GREATER THAN THE FLOW DEPTH FOR THE 10-YEAR EVENT.

Figure 13. An illustration of a diversion dike stormwater control structure.

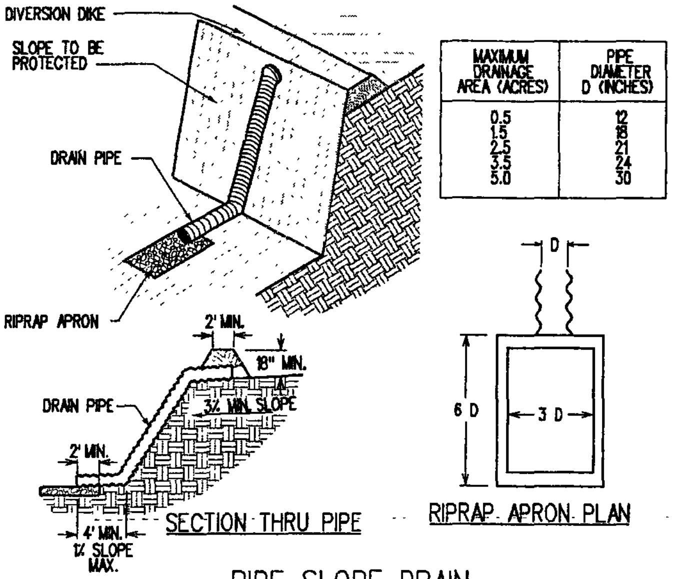


EXCAVATED SEDIMENT TRAP

NOTES:

1. EXCAVATED SEDIMENT TRAP MAY BE USED IN SMALL DRAINAGE AREAS LESS THAN 1 ACRE. WHERE OVERFLOW CAPACITY IS NEEDED AND IN AREAS OF HEAVY FLOW. 0.5 CFS OR GREATER.
2. THE DRAINAGE AREA SHOULD BE FAIRLY FLAT WITH SLOPES OF 5% OR LESS.
3. CONTRACTOR SHALL USE WASHED GRAVEL 3-5 INCHES IN DIAMETER TO A DEPTH OF AT LEAST 1 FOOT.
4. THE RECOMMENDED VOLUME OF THE SEDIMENT TRAP IS 35 CUBIC YARD PER ACRE DISTURBED.
5. THE CONTRACTOR SHALL REMOVE AND DISPOSE OF SEDIMENT WHEN IT ACCUMULATES TO HALF THE HEIGHT OF THE FILLER STONE.
6. WEEP HOLES SHALL BE FILLED WITH GROUT PRIOR TO BACKFILLING OF STORAGE.

Figure 14. An illustration of a sediment trap stormwater control structure.



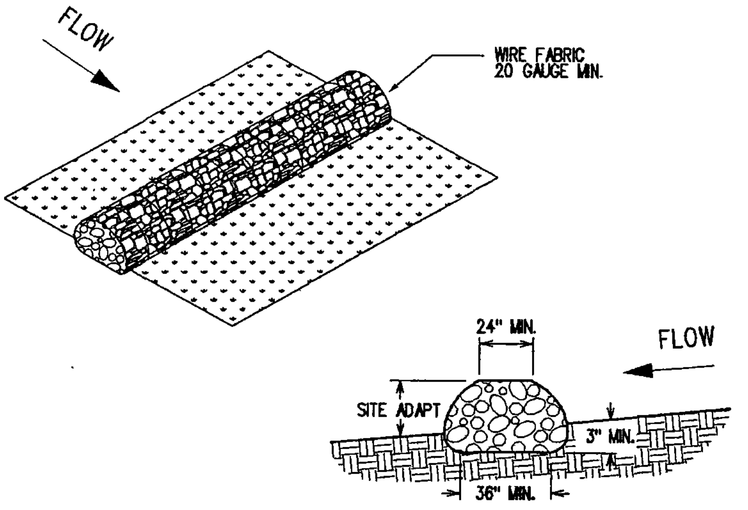
MAXIMUM DRAINAGE AREA (ACRES)	PIPE DIAMETER D (INCHES)
0.5	12
1.5	18
2.5	21
3.5	24
5.0	30

PIPE SLOPE DRAIN

NOTES:

1. MAXIMUM RECOMMENDED DRAINAGE AREA FOR PIPE SLOPE DRAINS IS 10 ACRES.
2. THE CONTRACTOR SHALL STABILIZE THE PIPE INLET AND OUTLET. A FLARED END SECTION SHOULD BE USED AT THE ENTRANCE OF THE PIPE. AND THE SOIL AROUND THE PIPE ENTRANCE SHOULD BE FULLY COMPACTED.
3. OUTLET RIPRAP SHALL CONSIST OF EITHER CRUSHED STONE OR BROKEN PORTLAND CEMENT CONCRETE. RIPRAP STONE SIZE SHALL BE 12 INCHES THICK
4. CONTRACTOR SHALL INSPECT THE OUTLET POINT FOR EROSION AND CHECK THE PIPE FOR BREAKS OR CLOGS.
5. DIKE HEIGHT SHALL BE A MINIMUM OF ONE FOOT GREATER THAN THE FLOW DEPTH FOR THE 10-YEAR EVENT.

Figure 15. An illustration of a pipe slope drain stormwater control structure.



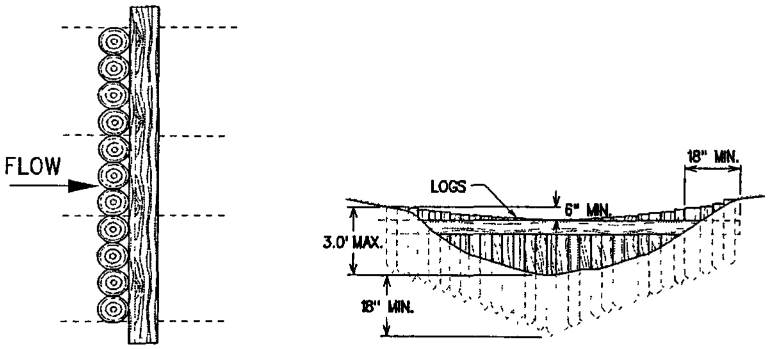
ROCK BERM OR CHECK DAM

NOTES:

1. USE ONLY OPEN GRADED ROCK 4-8 INCH DIAMETER FOR STREAM FLOW CONDITIONS. USE OPEN GRADED ROCK 3-5 INCH DIAMETER FOR OTHER CONDITIONS.
2. THE ROCK BERM SHALL BE SECURED WITH A WOVEN WIRE SHEATHING HAVING MAXIMUM 1 INCH OPENING AND MINIMUM WIRE DIAMETER OF 20 GAUGE.
3. CONTRACTOR SHALL REMOVE AND DISPOSE OF SEDIMENT WHEN IT ACCUMULATES TO ONE-THIRD THE HEIGHT OF THE BERM.
4. CHECK DAMS MAY BE INSTALLED IN STEEPLY SLOPED SWALES, OR IN SWALES WHERE ADEQUATE VEGETATION CANNOT BE ESTABLISHED. DAMS SHOULD NOT BE PLACED IN STREAMS.
5. CHECK DAMS SHALL BE SPACED SO THAT THE TOE OF THE UPSTREAM DAM IS AT THE SAME ELEVATION AS THE TOP OF THE DOWNSTREAM DAM.
6. CONTRACTOR SHALL INSPECT CHECK DAMS FOR SEDIMENT AND DEBRIS ACCUMULATION AFTER EACH SIGNIFICANT RAINFALL.

Figure 16. An illustration of a rock berm or check dam stormwater control structure.

TO A DEPTH OF 6".

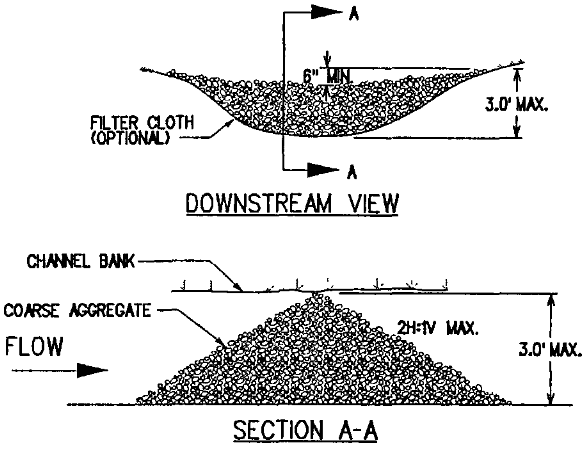


LOG CHECK DAM

NOTES:

1. CHECK DAMS MAY BE INSTALLED IN STEEPLY SLOPED SWALES, OR IN SWALES WHERE ADEQUATE VEGETATION CANNOT BE ESTABLISHED. DAMS SHOULD NOT BE PLACED IN STREAMS.
2. CHECK DAMS SHALL BE SPACED SO THAT THE TOE OF THE UPSTREAM DAM IS AT THE SAME ELEVATION AS THE TOP OF THE DOWNSTREAM DAM.
3. LOGS SHALL BE 6 TO 8 INCHES IN DIAMETER.
4. CONTRACTOR SHALL INSPECT CHECK DAMS FOR SEDIMENT AND DEBRIS ACCUMULATION AFTER EACH SIGNIFICANT RAINFALL.
5. CONTRACTOR SHALL REMOVE SEDIMENT WHEN IT REACHES ONE HALF THE ORIGINAL DAM HEIGHT.
6. CONTRACTOR SHALL INSPECT EDGES FOR EVIDENCE OF EROSION AT THE EDGES AND REPAIR PROMPTLY.

Figure 17. An illustration of a log check dam stormwater control structure.

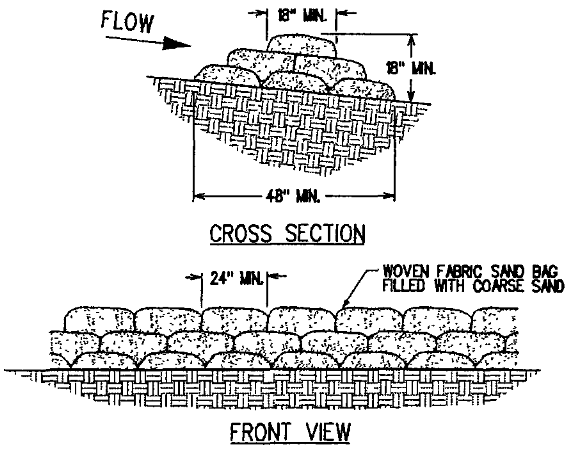


ROCK CHECK DAM

NOTES:

1. CHECK DAMS MAY BE INSTALLED IN DRAINAGE AREAS OF 2 ACRES OR LESS. IT SHOULD NOT BE USED IN A LIVE STREAM.
2. CHECK DAMS SHALL HAVE A MAXIMUM HEIGHT OF 3.0 FEET. THE CENTER OF THE DAM MUST BE AT LEAST 6 INCHES LOWER THAN THE OUTER EDGES.
3. CHECK DAMS SHALL BE CONTRUCTED WITH 5 TO 15 INCHES IN DIAMETER STONE.
4. FOR ADDED STABILITY, THE BASE OF THE CHECK DAM CAN BE KEYED INTO THE SOIL APPROXIMATELY 6 INCHES.
5. CHECK DAMS SHOULD BE SPACED SO THAT THE TOE OF THE UPSTREAM DAM IS AT THE SAME ELEVATION AS THE TOP OF THE DOWNSTREAM DAM.
6. FILTER CLOTH MAY BE USED UNDER THE STONE TO PROVIDE A STABLE FOUNDATION AND TO FACILITATE THE REMOVAL OF THE STONE.

Figure 18. An illustration of a rock check dam stormwater control structure.



SAND BAG BERM

NOTES:

1. SAND BAG BERM SHALL BE INSTALLED WHEN THE CONTRIBUTING DRAINAGE AREA IS GREATER THAN 5 ACRES.
2. SAND BAGS SHALL BE POLYPROPYLENE, POLYETHYLENE, POLYAMIDE OR COTTON BURLAP WOVEN FABRIC, MINIMUM WEIGHT FOUR OUNCES PER SQUARE YARD, MULLEN BURST STRENGTH EXCEEDING 300 PSI AND ULTRAVIOLET STABILITY EXCEEDING 70 PERCENT.
3. SAND BAGS SHALL BE 24 TO 30 INCHES IN LENGTH, 16 TO 18 INCHES IN WIDTH, AND 6 TO 8 INCHES IN THICKNESS.
4. SAND BAGS SHALL BE FILLED WITH COARSE GRADE SAND, FREE FROM DETERIOUS MATERIAL. ALL SAND SHALL PASS THROUGH A NO. 10 SIEVE. THE MINIMUM WEIGHT SHALL BE 40 LBS.
5. CONTRACTOR SHALL INSPECT SAND BAG BERMS AFTER EACH RAIN. THE SANDBAGS SHALL BE RESHAPED OR REPLACED AS NEEDED DURING INSPECTION.

Figure 19. An illustration of a sand bag berm stormwater control structure.

Aquatic Resources

Construction of a recommended plan would adversely impact approximately 13,336 linear feet of non-wetland jurisdictional waters of the United States. It is estimated that this project would adversely impact at least 15 runs, riffles, and pools. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of aquatic habitat consistent with providing the necessary level of flood protection. The avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of aquatic habitat consistent with providing the necessary level of flood protection.

Mitigation for Impacts to Aquatic Resources

It is always the mission of the Corps of Engineers to follow environmental directives to develop and implement a flood control plan that results in the least amount of adverse impacts to the natural ecosystem within a project area. The approach that the Corps takes when planning flood control projects is to first avoid as many natural resources as possible. Since many flood control projects occur in areas that also have high natural resource value, it is not always possible to totally avoid causing adverse impacts. In cases where avoidance is not possible, flood control projects are designed to minimize adverse impacts to the natural resources. And last, and least desirable, when avoiding and minimizing adverse impacts to natural resources is not possible, natural resources that would be lost as a result of a project are mitigated for.

The planning and design of the Willis Creek project implements the three facets that the Corps uses to reduce the adverse impacts to the natural environment. As indicated in the previous section, the Willis Creek project was carefully designed to avoid some very high quality natural resources. In this project at least 8 creek bends containing some superb natural resources were completely avoided by designing high flow swales that would carry floodwater across the terrestrial component of the creek bend during a storm event. The swales are designed as grass-lined earthen trapezoidal channels set at an elevation to begin receiving storm water flows equivalent to a two-year flood event. During all other times, base stream flows would be carried in the natural channel of the creek bend and the swale would be dry. Utilization of the high flow swales identified in the recommended plan for Willis Creek would preserve an estimated 2,344 linear feet of high quality riparian and aquatic habitat and non-wetland jurisdictional waters of the United States. In many areas throughout Willis Creek, it was necessary to design a flood control channel through areas that would adversely impact aquatic and terrestrial resources. Utilizing a channel design that excavated one side of the stream would minimize adverse impacts to the riparian and to some extent the aquatic community. Utilization of a one-sided channel design would allow the preservation of natural resources on one side of Willis Creek. The one-sided channel design would be implemented throughout almost the entire Willis Creek project. As indicated in the previous section, construction of a recommended plan for Willis Creek would adversely impact approximately 13,336 linear feet of non-wetland jurisdictional waters of the United States. It is estimated that this project would adversely impact at least 15 runs, riffles, and pools. In order to mitigate for the aquatic resources that would be adversely impacted, several features would be designed to be included into the flood control channel that would maintain stream stability and reestablish lost fish and benthic habitats. One of the first measures to mitigate for lost aquatic habitat would be to construct an earthen base flow channel in Willis Creek. The base flow channel would average approximately 10 feet in width and have an average depth of 2.5 feet. The dimensions are representative of the existing dimensions of Willis Creek. Willis Creek currently has a small natural base flow channel that meanders between the banks of the larger natural channel. The base flow channel that would be constructed in the proposed flood control channel would mimic the base flow streams' current sinuosity. Fifteen riffle crest structures constructed from natural stone would be placed in the base flow channel to create riffle and pool habitat. The riffle crest structures would have a V-shape crest down towards the center of the channel to direct flows away from the bank slopes and prevent erosion. The riffle crest structures would be placed along the base flow channel to create pool habitat in the same areas where pools are currently located in the natural channel. Guidance for the design of these structures can be found in "Stream Corridor Restoration, Principles, Processes, and Practices 1998". In addition to the mitigation measures previously described, native herbaceous vegetation would be allowed to colonize the invert of the flood control channel, and the top of the cleared bank would be planted with suitable hard mast producing tree species that would eventually generate a canopy contiguous with the existing trees on the opposite bank. It is estimated that the top of bank plantings would result in a restoration of 6.1 acres of riparian habitat immediately adjacent to Willis Creek. Shade from these trees would provide a thermal refuge and organic matter for the biota of Willis Creek.

In addition to implementing the above aquatic mitigation activities on site in the Willis Creek system, the Corps proposes to conduct aquatic mitigation off-sight by restoring a segment along a tributary of Willis Creek. The tributary identified for the aquatic mitigation activities is a 1,800 linear foot stretch of South Willis Creek in an area of Brownwood known as Festival Park. The aquatic mitigation site is located approximately one mile south of the project area and is a stream that had been previously channelized. The stream averages approximately 2 feet wide, and about 0.5 feet deep, has two small low water dams that create some pool habitat and has no meander character, or riffle and run habitat. The banks of South Willis Creek in this area contain sparse riparian vegetation that is limited to one side and the stream is littered with concrete rubble and domestic trash. Overall the aquatic habitat of the stream is very low. Restoration of South Willis Creek in Festival Park would consist of the following activities: construct a base flow channel (4 feet wide and 1 foot deep) in the system that would have a meandering pattern repeating at least four times throughout the 1,800 foot stretch; establish 5 boulder clusters (same as described for those placed in Willis Creek) throughout the reach to create small pools, riffle and runs; remove all debris from the system; and reestablish a vegetated riparian and no-mow zone 25 foot wide on both sides of the stream using the same criteria for planting diversity and success (80% survival of plants after 4 years) as indicated above for Willis Creek and the Fish and Wildlife Service Coordination Act requirements. This plan requires 2.5 acres. If in the event that at a later date the South Willis Creek area is unavailable for mitigation activities, another site indicated previously for terrestrial mitigation known as the "Bartholomew Place" would be a suitable area to do this work.

Terrestrial Resources

Construction of a recommended plan would adversely impact plant and animal terrestrial resources inhabiting the approximately 15.9 acres of old field habitat and 31.7 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old-field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Of the alternatives evaluated for the Willis Creek project, the recommended plan avoided the greatest abundance of terrestrial habitat consistent with providing the necessary level of flood protection. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife

1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document. The 404(b)(1) evaluation is presented at the end of the environmental appendix (Sub-Appendix G).

Section 401 – Clean Water Act

Section 401 of the Clean Water Act (33 U.S.C. 1341) requires that any activity which could result in a discharge of a pollutant into waters of the United States obtain a certification from the State in which the discharge would originate and that the discharge comply with applicable effluent limitations and water quality standards. The recommended plan for Willis Creek would be considered a Tier II project as detailed in the "Memorandum of Agreement Between the U.S. Army Corps of Engineers and the TNRCC. A Joint Public Notice for this project between the Corps and the TNRCC to inform the public and governmental agencies would be used to initiate a 30-day comment period for the TNRCC certification. This public review period would be the same one used for NEPA compliance. A decision of denial or approval of this project for Section 401 water quality certification would be rendered at the end of the public review.

Executive Order 11988 – Floodplain Management

Executive Order 11988, Floodplain Management, was considered during the planning of the proposed project. There are no practical alternatives to achieve the project purposes of flood damage reduction without working in the floodplain. Following project implementation, development of the Willis Creek floodplain would be managed. This would occur in accordance with Section 202(c) of the Water Resources Development Act of 1996, and the Federal requirement that within one year of project implementation, the city of Brownwood develop and submit an FPMP.

Executive Order 11990 – Protection of Wetlands

Executive Order 11990, Protection of Wetlands, was considered during planning of the proposed project. The recommended plan would not adversely affect or result in the loss of any wetland areas. The recommended plan would be in compliance with Executive Order 11990.

Executive Order 12898 – Environmental Justice

Executive Order 12898 provides that each Federal agency identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States. As proposed, recommended plan would not have disproportionate affects on minority or low-income populations.

Federal Threatened and Endangered Species

The recommended plan has been review by the U.S. Fish and Wildlife Service (See Appendix F). As proposed, the recommended plan would not adversely affect any Federal or State listed threatened, endangered, or special species or critical habitats.

Environmental Mitigation and Incremental Analysis

Every effort was made during the planning stages of this project to avoid or minimize adverse affects to terrestrial and aquatic natural resources. Unavoidable adverse affects by this project would be mitigated by replacement of lost natural resources with habitat of the same or greater functional capacity and quality. In mid-September 2000, with the cooperation of the U. S. Fish and Wildlife Service, several sites were identified as potential areas for mitigation in and around the city of Brownwood. A mitigation plan for adverse impacts to natural resources is jointly being developed between the Corps and the U.S. Fish and Wildlife Service.

The proposed mitigation for affected aquatic habitat would be to construct an earthen base flow channel in disturbed areas of Willis Creek. The base flow channel would be approximately 15 feet wide x 2.5 feet deep and mimic the streams' original sinuosity. Ten low-water retention structures would be placed at base grade along the stream to create pool habitat. Aquatic habitat in creek bends where a diversion channel is planned would be avoided. Base water flow would be maintained in these bend areas by constructing small dikes of low elevation across the inlets and outlets of the dversion channels. Further definition of the mitigation plan for aquatic habitat would occur during the development of project Plans and Specifications.

National Historic Preservation Act

The Recommended Plan would be in full compliance with the National Historic Preservation Act.

GENERAL AESTHETICS

Noise

It is expected that there would be short-term negative motorized noise during construction, however implementation of the Recommended Plan would add approximately 86.1 acres of new and improved forest habitat to the study areas. This would result in positive overall reduction of noise levels in the areas by buffering the sounds of traffic and general noises from the surrounding neighborhoods.

Lighting

Lighting is not included as part of the Recommended Plan. Therefore, there would be no adverse affects caused by lighting.

Traffic

There would be no long-term changes in traffic patterns with implementation of the Recommended Plan. Access would not be eliminated for any local residents. Short-term delays are to be expected during modification of the concrete box culverts at the 4th Street and 14th Street bridge crossings, but closure of the streets would not be warranted. There might be some temporary traffic inconveniences as trucks and equipment move along adjacent streets, but no more than short-term inconveniences would be expected.

Cultural Resource Impacts

No previous cultural resources assessment effort was performed within the project areas for this feasibility study. A previous reconnaissance visit in 1997 by a staff archeologist indicated a high potential for encountering archeological or architectural properties. Previous excavation efforts by others along Willis Creek and Pecan Bayou have also recorded archeological artifacts such as burned rock middens and Indian burial rock shelters. Eight archeological sites were recorded on Willis Creek in 1978 and 1980 and six additional sites recorded in 1987. None of the archeological sites nearest the project area has had the criteria for listing in the NRHP applied, but the majority of the sites recorded were reported as having some integrity and some with significant depth. The lower reach of Willis Creek nearest the confluence with Pecan Bayou will be of particularly high sensitivity for impacts to archeological properties as several archeological sites have already been identified in the area south of the water treatment plant.

While an inventory has not been completed for any of the project areas to determine the existence of standing historic buildings and structures, including any bridges crossing the project areas, the potential for such properties within the areas of potential effect exists. The likelihood of historic period archeological sites within the project limits appears marginal and the available historic data does not indicate the previous existence of buildings from an earlier period. The project area will require individual inventorying and possibly an NRHP assessment depending on the age, context, and design of the properties.

Economic Summary

Listed below, in Table 16, is an Economic Summary for the Recommended Plan detail the Total Project Cost.

Table 16 Total Project Cost

Project Cost:	
Relocations	$ 602,900
Fish & Wildlife	$ 757,090
Roads, Railroads, & Bridges	$ 639,246
Channels and Cannels	$2,433,652
Total Construction Cost	$4,432,888
Land and Damages	$2,990,577
Planning, Engineering, & Design	$ 442,388
Supervision and Administration	$ 404,337
Total Project Cost	**$8,270,190**
Interest During Construction	$ 379,931
Total Investment Cost	$8,650,121
Construction Period (months)	**18**
Annual Cost:	
Interest (6.375%)	$ 529,820
Amortization (50-years)	$ 28,580
Operations and Maintenance	$ 15,600
Replacements	$0
Total Annual Cost	**$ 574,000**
Total Annual Benefit	**$ 887,600**
Benefit-Cost Ratio	**1.55**
Net Benefits	**$ 313,600**

As noted, the total economic cost of the Recommended Plan would be approximately $8,270,190. The plan would have annual cost of $529,820, total annual benefits of $887,600, net annual benefits of $313,600, and a BCR of 1.55.

Project Cost Sharing

The provisions of the Water Resources Development Act of 1996 (Public Law 104-303), approved October 12, 1996, stipulates cost sharing requirements which local sponsors must meet for the Federal Government to be involved with water resource projects. Cost sharing provisions for the flood control, ecosystem restoration, and recreational development purposes are outlined below.

Flood Damage Reduction

Under the provisions set forth in Public Law 104-303, as amended, the designated Sponsor would be required to formally approve the recommendations of the Interim Feasibility Report before initiating the Preconstruction, Engineering, and Design Phase of the project.

For non-structural flood control projects, the non-Federal cost would be 35 percent of total project flood control costs. The non-Federal sponsor would be responsible for 100 percent of the operations, maintenance, repair, rehabilitation and replacement costs of the project.

For structural flood control projects, the non-Federal requirements would consist of Land, Easements, Right of Ways, Relocations, and Disposal areas (LERRDs), plus 5% cash contribution must be at least 35%, but no more than 50% of the project cost.

Ecosystem Restoration

Public Law 104-303, as amended, states that the non-Federal cost for ecosystem restoration projects would be 35 percent of the total ecosystem restoration project costs. The non-Federal sponsor would be responsible for 100 percent of the operations, maintenance, repair, rehabilitation, and replacement costs of the project. The city of Brownwood did not have any interest in pursuing any ecosystem restoration features.

Recreational Development

The recommended plan for Willis Creek is a hydraulic channel improvement project for the purpose of flood damage reduction project and the city of Brownwood did not have interest in pursuing any recreational features. Therefore, this study does not contain any recreational developments, however future considerations by the city could offer walking trails through the mitigation areas once the site is established and there are no adverse impacts to the mitigation areas.

Operation, Maintenance, Repair, Rehabilitation, & Replacement

The Federal Government and the city of Brownwood will enter into a project cooperation agreement (PCA) in which the city would accept the project following completion of construction, and ensure operation, maintenance, repair, rehabilitation and replacement (OMRR&R), in accordance with Federal regulations. Annual OMRR&R costs are estimated at $15,600.00. This includes mowing (3 times yearly) to regulate grass height and reduce woody-growth buildup, bi-annual fertilizing of the native grass to maintain adequate groundcover and prevent erosion, annual herbicidal applications as needed to control woody growth, general maintenance & clean-up, and removal of sediment buildup throughout the channel. Mowing and other intensive maintenance activities on environmental mitigated areas should be restricted whenever possible to the late fall and winter months in order to provide optimum wildlife food and cover during the spring and summer reproductive season, and that no mowing should occur on the designated wildlife mitigation lands following successful reestablishment of woody vegetation. A non-maintenance herbaceous riparian corridor will be maintained a minimum of 5 ft from the edge of the base flow stream. In addition, a forested riparian corridor will also be established along the top of bank where impacted by the one-sided excavation. Specified limited access points at the top of channel, typically near major road crossings, will be required for channel maintenance vehicles. An Operations and Maintenance Manual will be prepared by the Fort Worth District after completion of the project, and periodic inspections would be conducted in ensure that all required maintenance is being performed by the city of Brownwood.

PLAN IMPLEMENTATION

DIVISION OF RESPONSIBILITIES

Project Cost Apportionment

This section presents the appropriate sharing of costs between the Federal and non-Federal interests for the Recommended Plan. The total cost of this plan was estimated at $8,270,190. The Federal cost would total approximately $4,135,095 (50%), while the non-Federal cost would equal approximately $4,135,095 (50%).

The costs shown below, in Table 17, are based on standard requirements set forth in Public Law 104-303, as amended, for each of the project purposes. Under these laws, non-Federal interests would be required to furnish all lands, easements, rights-of-way, and disposal areas, and perform all relocations of bridges and utilities.

Table 17 Cost Apportionment

	Federal	City of Brownwood
Land, Easements, & Right of Ways		$ 2,990,577
Relocations		
Utilities		$ 602,900
Roads, Bridges, Railroads		$ 639,246
Channels	$2,433,652	
Fish & Wildlife Mitigation	$ 757,090	
Engineering and Design	$ 331,791	$ 110,597
Supervision and Administration	$ 323,470	$ 80,867
Subtotal	$ 3,846,003	$ 4,424,187
5% Cash Contribution	$ (413,509)	$ 413,509
Subtotal	$ 3,432,494	$ 4,837,696
Adjust for 50% of Project Cost	$ 702,601	$ (702,601)
Total Cost Sharing Apportionment	**$ 4,135,095**	**$ 4,135,095**

Total project cost = $8,270,190

Non-Federal Responsibilities

Having considered the social, economic, environmental, and engineering aspects of providing a flood damage reduction project for the city of Brownwood, Willis Creek, a project to reduce flood damages has been identified and is in the overall public interest. Accordingly, the recommended plan, as described in this report, is recommended to be authorized for implementation with such modifications as the Chief of Engineers may find advisable, and in accordance with existing cost sharing and financing requirements. The total first cost of the project, based on 2001 price levels, is estimated at $8,270,190, with annual operation, maintenance, and repair costs estimated at $15,600.00. The final non-Federal responsibilities will be detailed in the Project Cooperation Agreement. In addition, a Preconstruction Engineering and Design (PED) agreement will be executed for the project prior to preparation of plans and specifications. This recommendation is also subject to the nonfederal sponsor agreeing to comply with applicable Federal laws and policies, including the following requirements:

A. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs and further specified below:

B. Enter into an agreement which provides, prior to construction, 25 percent of preconstruction, engineering, and design (PED) costs;

C. Provide, during construction, any additional funds needed to cover the non-federal share of PED costs;

D. Provide, during construction, a cash contribution equal to 5 percent of total project costs;

E. Provide all lands, easements, and right-of-ways, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operations, and maintenance of the project;

F. Provide or pay to the Government the cost of providing all retaining dikes, wasteweirs, and embankments, including all monitoring features and stilling basins, that may be required at any excavated material disposal areas required for the construction, operation, and maintenance of the project; and

G. Provide, during construction, any additional costs as necessary to make its total contribution equal to 35 percent of total project costs.

H. For so long as the project remains authorized: operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Government, in accordance with applicable Federal and state laws and any specific direction prescribed by the Government.

I. Grant the Government a right to enter, at reasonable times and in a reasonable manner, upon land with the local sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating, the project.

J. Assume responsibility for operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the project or completed functional portions of the project, including mitigation features without cost to the Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

K. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Lay 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into written agreement to furnish its required cooperation for the project or separable element.

L. Hold and save the Government free from all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterment, except for damages due to the fault or negligence of the Government or the Government's contractors.

M. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly reflect total project costs.

N. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements or right-of-ways necessary for the construction, operation, and maintenance of the project.

O. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or right-of-ways that the Government determines necessary for the construction, operation, or maintenance of the project. The Government shall assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated material within Federal properties.

P. To the maximum extent practicable: operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

Q. Prevent future encroachments on project lands, easements, and right-of-ways, which might interfere with the proper functioning of the project.

R. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisitions Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and right-of-ways, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with the said act.

S. Comply with all Federal and State laws and regulation, including Section 601 of the Civil Rights Act of 1964, Public Law 88-352, and department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination of the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army".

T. Provide 35 percent of that portion of total cultural resource preservation mitigation and data recovery costs attributed to structural flood control that are in excess of one percent of the total amount authorized to be appropriated for structural flood damage reduction.

U. Participate in and comply with applicable Federal floodplain management and flood insurance programs and comply with the requirements in Section 402 of the Water Resources Development Act of 1986, as amended.

SUMMARY OF COORDINATION, PUBLIC VIEWS, AND COMMENTS

PURPOSE OF PROGRAM

This Feasibility Study focused on the development of an economically feasible, environmentally acceptable, publicly supportable solution to the flooding problems within the city of Brownwood. Several meetings and conversations with city officials have been held with the various entities and interested citizens to share the latest possible information and to focus this study toward investigating the most viable alternatives. In addition, various public workshops and meetings were held in the study areas for the citizens to give input in the problems and possible solutions, as stipulated by Public Law 99-662 and Public Law 104-303.

PARTICIPANTS

Study participants worked closed over the study period in an effort to inform and involve the concerned citizens in the study area. The agencies involved in this effort included the Fort Worth District Corps of Engineers, city of Brownwood, the Texas Water Development Board, and the United States Fish and Wildlife Service.

PUBLIC WORKSHOPS AND MEETINGS

On September 12 & 13, 1994, a public meeting was held during an extended city council meeting to receive input from the citizens on the future of the Willis Creek and Adams Branch and to discuss Federal participation for flood damage reduction opportunities.

On November 19, 1996, a Feasibility Study Public Workshop meeting was held in the city of Brownwood during an extended city council meeting to gather citizen input and to provide an overview of the Feasibility Study.

In 1998, a public meeting was held in coordination with an extended city council meeting to discuss the progress of plan formulation of Willis Creek and Adams Branch and to receive input from the citizens of Brownwood.

On June 26, 2001, a public meeting was held during a city council meeting to inform the city council and general public of the recommended plan and to visually show with and without project conditions for the 100 year flood event.

PUBLIC REVIEW

The draft Interim Feasibility Report and Integrated Environmental Assessment was prepared and sent out to the Brownwood Public Library and City Hall on August 03, 2001 for a 30-day public comment period. A special public meeting was held on August 16, 2001 in the city of Brownwood to allow the city council and general public to provide input and comment on the recommended plan. Approximately 50 citizens attended this meeting. In addition, the recommended plan was also placed on the Fort Worth District's Home web page for public viewing. The review period ended September 03, 2001.

FINANCIAL ANALYSIS – SOCIOECONOMIC EFFECTS OF PLAN IMPLEMENTATION

The potential economic and social effects from implementation of the Recommended Plan on the study area are comprised of the value of the long-term reduction in periodic flood damages, direct and indirect short-term income, and employment impacts of project construction. The permanent reduction in periodic flood damages would effectively increase the income available to floodplain property owners released from the financial burden inherent to residing in the floodplain.

To the extent that this additional disposable income is spent within the city, it would result in a local "multiplier effect". Increases in business revenues, employment, and personal income rippling throughout the local economy as each new dollar brought in is spent and re-spent. Property values, and local tax revenues cold also increase as a general result since the public perception of the area would be improved by project implementation.

In addition, short-term employment effects associated with project construction would stimulate increased demand locally for construction materials and services. These expenditures would be expected to result in a positive multiplier effect on the local economy and would last for about two years.

Given the small scale of the Recommended Plan, the short-term impacts associated with construction would be temporary and insignificant relative to the overall local economy as a whole. Eventually, the only lasting economic and social effects of project implementation would be the benefits resulting from the permanent reduction in flood damages and the designation of the land for recreational and restoration purposes.

NON-FEDERAL FINANCIAL PLANNING

The purpose of strategic financial planning is to optimize the use of capital over time in response to long-term financial goals. The three principal elements involved include cost recovery alternatives, selection of the preferred financing alternative, and implementation of the cost recovery approach. Although financing decisions are ultimately the sponsors', the Corps of Engineers can assist in the decision making process through the provision of timely information on costs, benefits, and cost recovery opportunities. The sponsor is responsible for making arrangements to finance the project sufficiently in advance of construction to enable the project schedule to be met. A financial capability assessment of the non-Federal Sponsor is required prior to execution of the Plan and Specification Phase. The City has indicated that funding for the proposed project would be through issuance of a General Obligation Bond. Maintenance and Operations costs would be covered through the City's annual budget.

ABILITY-TO-PAY ANALYSIS

Based on ER 1165-2-121, an ability-to pay test should be applied to all flood control projects. The test determined the eligibility of the study area to quality for a reduction in the amount to be cost shared by the non-Federal interest. To qualify for a reduction, the results of both the benefit and income portions of the twofold ability-to-pay test must fall within the specified guidelines.

The benefits' test determines the maximum reduction, called the "benefits based floor" (BBF), in the level of non-Federal cost sharing for any project. The factor is determined by dividing the project B/C ratio 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 WRDA 86 authorized cost share level for the Flood Protection project is 25 percent. The Recommended Plan's B/C ratio of 2.0 was divided by four to yield a BBF of .50 or 50 percent.

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

In accordance with factors released in Economic Guidance 96-4, the income index factors for the state of Texas and Brown County are 90.81 and 102.77, respectively. The Eligibility Factor (EF) for a flood control project is calculated according to the following formula:

$$EF = a - b_1 * (\text{State factor}) - b_2 * (\text{area factor}) \text{ where:}$$

$a = 15.86794$

$b_1 = 0.06771$

$b_2 = 0.13543$

Using the above formula, an EF of -4.2 was calculated for the city of Brownwood. An EF below zero indicates ineligibility for a reduction in construction cost sharing. As stated previously, a BBF factor for the investigated plan was calculated at 50 percent. To qualify for a reduction, the BBF factor must be less than the authorized level of cost sharing in accordance with ER-1165-2-121 paragraph 5a(2). The city of Brownwood does not meet the criteria for a reduction in construction cost since this project meets neither test. Therefore, the city of Brownwood must pay the currently authorized cost share level.

RECOMMENDATIONS

As indicated earlier, the primary planning objective for this feasibility level investigation was to determine the most economically and environmentally feasible plan to substantially alleviate the flooding problems within the Pecan Bayou watershed within the city of Brownwood.

The National Economic Development Plan (NED) identified in this investigation would consist of 15,680 feet of hydraulic channel improvement of Willis Creek within the city of Brownwood. The improvement would consist of reshaping the existing channel into a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal with a bottom width of 40 feet with pilot channel. The channel depth would vary between 4 and 11 feet deep with the top varying between 40 to 135 feet wide. A diversion channel will be constructed approximately 1200 feet downstream of 14th Street Bridge to the 4th Street Bridge. The improvement will also require box culvert modifications to the 14th Street Bridge and 4th Street Bridge, side slope modifications at Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection. Environmental mitigation measures would consist of bypassing several oxbows and allowing them to serve as wildlife habitat and wetlands. Approximately 102.1 acres of reforestation/prairie restoration will be undertaken to replace the habitat removed by the channel excavation.

CONCLUSIONS

The following conclusions and recommendations are made in connection with the study findings of these investigations:

1. A significant need for a local flood damage reduction project within the Willis Creek, Brownwood, study area exists. This plan would reduce expected annual damages of by 92 percent; eliminate all damages caused by the 10 percent ACE event and nearly 90 percent of the damages caused by the 1-percent event.

2. The overall flood damage reduction plan would have estimated first costs of $8,270,190, annual cost of $574,000, net benefits of about $313,600, and a benefit-to-cost ratio of 1.55.

3. The city of Brownwood was identified as the local sponsor for construction of the project. Federal and non-Federal cost apportionments for the Recommended Plan were estimated at $4,135,095 (50%) Federal and $4,135,095 (50%) non-Federal.

4. The Recommended Plan will cause no significant environmental impacts within the study area. A Finding of No Significant Impacts (FONSI) has been prepared and is included herein. Distribution of this report, including the FONSI, was made to the public for review on August 03, 2001.

5. The City of Brownwood has provided a letter dated December 18, 2001 requesting the Corps of Engineers to begin the Plans and Specifications phase of the project.

6. The City of Brownwood has provided a letter dated April 19, 2002 indicating that their portion of funding for the proposed project would be through the issuance of a General Obligation Bond by public vote. Maintenance and Operation costs would be covered through the City's annual budget.

RECOMMENDATIONS

I offer the following recommendations:

1. The flood damage reduction measures identified as the Recommended Plan for the Willis Creek, Brownwood, study area be authorized for construction.

2. Prior to project implementation, the non-Federal sponsor shall enter into a binding agreement with the Secretary of the Army to perform the items of local cooperation, as specified in this document.

3. This recommended project be converted from the General Investigations Program authority to the Continuing Authority Program authority due to the project cost, size, and scope. This will allow for a more timely implementation of the project.

The above recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However prior to transmittal to the Congress, the sponsor, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Gordon M. Wells

Gordon M. Wells
Colonel, Corps of Engineers, Fort Worth District
Commander and District Engineer

LIST OF PREPARERS

The individuals who were primarily responsible for contributing to the preparation of the Interim Feasibility Report are listed below.

List of Preparers

NAME	DISCIPLINE	STUDY ROLE
Thomas Vogt	Project Manager	Project Management
Jason Foltyn	Lead Planner	Report Preparation
Craig Loftin	Hydrology and Hydraulics	Hydrologic and Hydraulic Analysis
Julie Gibbs	Economics	Economics Analysis
Kenneth McCleskey	Geotechnical	Geotechnical Design Analysis
Larry Mendoza	Civil Engineering	Civil Design Analysis
William Sanner	Structural Engineering	Structural Design Analysis
Blake Bryant	Realty Specialist	Real Estate Analysis
Hank Jarboe	Environmental Resources	Environmental Assessment Analysis
Jay Newman	Cultural Resources	Cultural Assessment
Wayne Elliott	Environmental Design	HTRW Analysis
Jim Sears	Cost Engineering	Cost Estimating
U.S. Fish and Wildlife	Environmental Assessments	Coordination Act Report

FINDING OF NO SIGNIFICANT IMPACT
Local Flood Protection Project (Section 205)
WILLIS CREEK, BROWNWOOD, TEXAS

Willis Creek originates about five miles southwest of Brownwood, Texas, and flows generally north and then east, passing through the southern Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. At the request of Brownwood, the U.S. Army Corps of Engineers initiated studies under the authority of Section 205 of the Flood Control Act of 1948, as amended, to evaluate potential solutions to flooding problems associated with Willis Creek within the city limits of Brownwood.

Structural and nonstructural alternatives that were evaluated for consideration included flood regulation, flood forecasting and warning, flood proofing, flood plain management, permanent relocation, detention ponds, levees, hydraulic channels, and bridge relocations. The hydraulic channel was the only alternative that proved economically, technically, and socially feasible. Hydraulic channels with bottom widths of 10, 20, 45, and 60 feet were evaluated for further consideration. A 40-foot bottom width hydraulic channel alternative approximately 15,680 long was incrementally selected as the Recommended Plan.

The proposed plan for Willis Creek local flood damage reduction would be a hydraulic channel improvement approximately 15,680 feet long beginining near Asbury Street, and extending approximately 6,400-feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel would be excavated across an open field, reconnecting to Willis Creek about 2,000-feet downstream (approximately 500-feet upstream of 4th Street). The improved channel would proceed 7,880-feet to the downstream terminus of the plan. The improved channel, including the diversion channel would have an average bottom width of 40-feet, with side slopes of 1 vertical on 3.5 horizontal. The plan would require modifications to two box culvert crossings. The four existing 8-foot by 6-foot culverts at 14th Street would be replaced with eight 10-foot by 10-foot culverts. Three 10-foot by 8-foot culverts would be added to the four existing 10-foot by 8-foot culverts on 4th Street. Riprap would be placed at the bridge approaches for erosion protection. Approximately 545-feet of different types of storm drain (reinforced concrete and galvanized pipe) would be extended. In addition, approximately 1,581-feet of various sanitary sewer, water, and gas utility lines would be relocated.

This plan reduces expected annual damages by 92 percent; eliminates all damages caused by the 10 percent ACE event and nearly 90 percent of the damages caused by the 1-percent event.

The Recommended Plan and other feasible alternatives were evaluated for impacts to cultural resources and the natural and human environment. As proposed, The Recommended Plan would have no adverse affects on cultural resources, beneficial affects to the human environment by providing flood protection, and adverse affects to the terrestrial and aquatic ecosystem of Willis Creek. The Recommended Plan would adversely affect an estimated 15.9 acres of old field and 31.7 acres of forested habitat.

During public review of the draft Feasibility Report/Environmental Assessment, comments by the TNRCC led to the development of a revised aquatic mitigation plan. This plan and minor modification of the terrestrial mitigation plan as described in the Feasibility Report/Environmental Assessment was fully coordinated with TNRCC. The TNRCC subsequently issued a water quality certification under Section 401(a) of the Clean Water Act as a result of the inclusion of the aquatic and terrestrial mitigation plans to the report.

The possible consequences of the recommended plan have been considered in accordance with Sections 404 and 401 of the Clean Water Act. The Recommended Plan would result in adverse affects to approximately 13,336 linear feet of channel and 9.1 acres of waters of the United States. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document. The proposed project is in compliance with Section 401 of the Clean Water Act.

Based upon the Environmental Assessment and results of coordination, I have concluded that the proposed action would not have a significant adverse affects on the human or natural environment. Consequently, construction of the proposed project would not constitute a major Federal action of sufficient magnitude to warrant the preparation of an Environmental Impact Statement.

1 April 2002

Date

Gordon M. Wells

Gordon M. Wells
Colonel, Corps of Engineers
District Engineer

APPENDIX A

ENGINEERING

SUB-APPENDIX A

HYDROLOGY

SUB-APPENDIX A

HYDROLOGIC ANALYSIS

BASIN DESCRIPTION

The Pecan Bayou watershed is located in the north-central portion of the Colorado River Basin, near the geographical center of Texas. It is bounded on the north and east by the respective watersheds of the Clear Fork and Leon River tributaries of the Brazos River, and on the west and south by watersheds of small tributaries of the Colorado River. This pear-shaped watershed has an overall length of about 85 miles, a maximum width of about 40 miles, an average width of about 26 miles, and a total drainage area of about 2,200 square miles. The watershed comprises portions of Taylor, Callahan, Eastland, Runnels, Coleman, Brown, Comanche, and Mills Counties. The Willis Creek watershed is situated within and adjacent to southern portions of the city of Brownwood.

The North Prong of Pecan Bayou originates about 10 miles southeast of Abilene. It proceeds in a southeasterly direction, crosses Farm Road 604, passes through Clyde Lake, and then proceeds in a more southerly direction, crossing State Highway 36, prior to reaching its confluence with the South Prong. The North Prong watershed comprises about 110 square miles of drainage area. The South Prong originates at the "Callahan Divide", about 13 miles south-southeast of Abilene. It proceeds in an easterly direction and crosses Farm Road 604, prior to reaching its confluence with the North Prong. The South Prong watershed comprises about 79 square miles of drainage area. At this location, the Pecan Bayou watershed comprises about 189 square miles of drainage area. From this point, Pecan Bayou proceeds in a southeasterly direction, crossing U.S. Highway 283, State Highways 206 and 279, and Farm Road 2559, at which point it enters Lake Brownwood. The total contributing drainage area at this point is about 658 square miles. A major left-bank tributary, Hog Creek, joins Pecan Bayou about 2,000 feet downstream of Farm Road 2559. The total drainage area below the confluence of Hog Creek is about 741 square miles. Lake Brownwood is comprised of two major arms, that of Pecan Bayou and that of Jim Ned Creek. The total drainage area of Pecan Bayou, above the general confluence of Jim Ned Creek, is about 780 square miles.

Jim Ned Creek originates about 18 miles south-southwest of Abilene, near Lake Abilene, of the Brazos River Basin. It proceeds in a southeasterly direction, crossing U.S. Highways 83 and 84, and Farm Road 604, prior to entering Lake Coleman. It then crosses U.S. Highway 283 and State Highway 206, before reaching the confluence of Hords Creek, a major right bank tributary. The total drainage area of Jim Ned Creek, above the confluence of Hords Creek, is about 450 square miles. Hords Creek originates about 17 miles west-northwest of Coleman and proceeds in a southeasterly direction, crossing Farm Road 53, prior to entering Hords Creek Lake. It then proceeds in a more easterly direction, crossing Farm Roads 503 and 53, U.S. Highway 283, and Farm Road 1176, prior to reaching its confluence with Jim Ned Creek. The Hords Creek watershed comprises about 148 square miles of drainage area. The total drainage area below the confluence of Hords Creek is about 597 square miles. From this point, Jim Ned Creek proceeds in a southeasterly direction, crosses Farm Road 585, and enters Lake Brownwood, near "Keeler Knob". The total drainage area at this point is about 716 square miles. The Jim Ned Creek arm of Lake Brownwood is crossed by State Highway 279. The total drainage area of Jim Ned Creek, above its general confluence with Pecan Bayou, is about 786 square miles, while the total drainage area of Pecan Bayou, at the Lake Brownwood dam is about 1,566 square miles.

Below the Lake Brownwood spillway, Pecan Bayou proceeds in a southerly direction toward the city of Brownwood. A major left bank tributary, Salt Creek, which joins Pecan Bayou in this reach, has a total drainage area of about 45 square miles. Pecan Bayou enters

Brownwood near U.S. Highway 67/377, at which point the total drainage area is about 1654 square miles. Below this point it crosses Woodson Road, and then proceeds in a southeasterly direction to the confluence of Adams Branch, a major right-bank tributary. Adams Branch drains the north and western portions of the city and has a total drainage area of about 34 square miles. A short distance further downstream, Pecan Bayou is joined by Delaware Creek (14 square miles), and then passes beneath the Atchison-Topeka-Sante Fe Railroad (ATSF RR) bridge, prior to reaching the confluence of Willis Creek. The total drainage area above this point is about 1,707 square miles.

Willis Creek, which drains the southern portions of Brownwood, originates a few miles south-southwest of the city and proceeds in a northerly direction to the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) floodwater retarding site "Brownwood Laterals #3", at which point the total drainage area is 9.20 square miles. Below the damsite, it proceeds in an easterly direction to U.S. Highway 377, below which it continues in a more northeasterly direction, crossing Crockett Drive and a small railroad spur. From this point it proceeds in an easterly direction, crossing Custer Road and Southside Drive, prior to reaching the confluence of South Willis Creek. The total drainage area of Willis Creek above this point is 12.55 square miles.

South Willis Creek originates a few miles due south of Brownwood and proceeds in a northerly direction to SCS floodwater retarding site "Brownwood Laterals #4A", at which point the total drainage area is 0.84 square miles. Below the damsite, it proceeds in a northerly direction, crossing Farm Road 45 (the south loop), Milam Drive, Morris Sheppard Drive, Stephen Austin Drive, and 4th Street (Southside Drive), prior to reaching its confluence with Willis Creek. Another prominent feature of this watershed is SCS floodwater retarding site "Brownwood Laterals #4B", which is situated on the "Country Club" tributary and partially controls runoff from 1.14 square miles of drainage area. The total drainage area of South Willis Creek is 10.68 square miles. The total drainage area of Willis Creek, below the confluence of South Willis Creek, is 23.23 square miles.

From this point, Willis Creek proceeds in an easterly direction, crosses Austin Avenue, and eventually reaches its confluence with Pecan Bayou, about 2,000 feet downstream of the ATSF RR bridge. The total drainage area of Willis Creek is 28.42 square miles.

The total drainage area of Pecan Bayou, below the confluence of Willis Creek is about 1,736 square miles. From this point it proceeds in an easterly direction to Farm Road 2126 (the east loop), continues in a southeasterly direction to the confluences of Steppes Creek (35 square miles) and Lewis Creek (8 square miles), below which Pecan Bayou has a total drainage area of about 1,780 square miles. It then proceeds in a southeasterly direction to the "Tenmile Crossing", below which it continues past the confluences of Doudle Creek (15 square miles), Devils River (7 square miles), Mackinally Creek (15 square miles), Pecan Creek (6 square miles), Long Branch (4 square miles), Fisk Creek (13 square miles), and Rough Creek (7 square miles), before turning in an eastward direction toward the confluence of Blanket Creek, a major left bank tributary (196 square miles). The total drainage area of Pecan Bayou below the confluence of Blanket Creek is about 2,083 square miles. Pecan Bayou proceeds in a southeasterly direction about 3,000 feet, prior to reaching State Highway 573. The watershed runoff model prepared during this study was terminated at this point, where the total drainage area is about 2,084 square miles. Pecan Bayou continues in a southerly direction and crosses State Highway 577, prior to reaching its confluence with the Colorado River. This point is about 10 miles west-southwest of Goldthwaite and about 25 miles southeast of Brownwood. As a comparison, the U.S. Highway 377 crossing in Brownwood is about at river mile 48. The total Pecan Bayou drainage area of about 2,200 square miles, specified earlier in this writeup, was taken from prior studies.

A general basin map (of Pecan Bayou) is provided in Plate 1. A more detailed basin map of the Willis Creek watershed is provided in Plate 2.

Elevations within the Pecan Bayou watershed range from about 2,370 feet National Geodetic Vertical Datum (NGVD) at the headwaters of Jim Ned Creek, to about 1,150 feet NGVD at the confluence with the Colorado River. This is a total drop of about 1,220 feet over about 154 miles, representing an overall average slope of about 8 feet per mile (fpm). Elevations specifically within the Willis Creek watershed range from about 1,620 feet NGVD, at the common divide with Adams Branch, to about 1,280 feet NGVD at the confluence with Pecan Bayou. This is a total drop of about 340 feet over about 10.3 miles, representing an overall average slope of about 33 fpm.

The following section was taken from the "Review of Reports on Pecan Bayou Watershed, Colorado River Basin, Texas, prepared by the Fort Worth District (FWD) of the U.S. Army Corps of Engineers (USACE) in 1963.

> **PHYSICAL CHARACTERISTICS OF THE WATERSHED.**- The Pecan Bayou watershed lies principally within the Central Texas section of the Interior Plains physiographic province. The watershed portions which are upstream and downstream from approximately the Brown-Coleman County line are principally within the Rolling Plains and the North Central Prairies land-resource areas, respectively. The watershed is characterized by plateaus in maturity and later stages of erosion with areas of well-developed and rapid drainage and moderate relief ranging from relatively smooth plains to sharply eroded valleys. The watershed soils are sandy loams, clay loams, clays, and stoney soils, ranging from neutral to slightly calcareous or to slightly acid, and from dark brown to reddish brown or to grayish brown. The soils within the main stream valleys are alluvial. The watershed vegetation is principally grasses, mesquite, and scrub oak.
>
> **GEOLOGY.**- The watershed lies within outcrop of the Pennsylvanian, Permian, and Lower Cretaceous strata. The outcrops consist principally of clays, sands, shales, sandstones, limestones, conglomerates, marls, and gypsums.

The following section provides general information and pertinent data concerning the major reservoirs within the Pecan Bayou watershed.

Clyde Lake: This reservoir is located on the North Prong of Pecan Bayou, about 14 river miles above the confluence of the South Prong of Pecan Bayou. It collects runoff from 37.33 square miles of drainage area. It was designed by the SCS, as floodwater retarding structure number 7 on the upper Pecan Bayou watershed. It provides municipal and industrial water supply for the City of Clyde, and has a conservation storage of 5,754 acre-feet. It was implemented in 1969.

Lake Coleman: This reservoir is located on Jim Ned Creek, about 50 river miles above the confluence with Pecan Bayou. It collects runoff from 305.06 square miles of drainage area. It was designed by Forest and Cotton, Inc. It provides municipal and industrial water supply for the City of Coleman, and has a conservation storage of 38,846 acre-feet. It was implemented in 1966.

Hords Creek Reservoir: This reservoir is located on Hords Creek, about 28 river miles above the confluence with Jim Ned Creek. It collects runoff from 49.06 square miles of drainage area. It was designed by the FWD USACE. It provides flood control, water supply, and recreation, and has a total storage (below flood control pool level) of 24,500 acre-feet. It was implemented in 1948.

Lake Brownwood: This reservoir is located on Pecan Bayou, about 57 river miles above the confluence with the Colorado River. It collects runoff from about 1,544 square miles of drainage area. It was constructed and operated by the Brown County Water

Improvement District (WID) Number 1. It provides agricultural, municipal, and industrial water supply and recreation for much of the Brownwood area, and has a conservation storage of 118,438 acre-feet. It was implemented in 1932.

More details on these projects are provided in the main narrative of the feasibility report. In addition to these major reservoirs, numerous floodwater retarding structures have been constructed by the SCS. Clyde Lake itself falls under this category, since it was originally "Upper Pecan Bayou #7". Altogether, 38 have been constructed within the portion of the Pecan Bayou watershed upstream from Lake Brownwood. These structures, which partially control runoff from about 251 square miles, have a total flood control storage capacity of 46,522 acre-feet. 38 have also been constructed within the Jim Ned Creek watershed, with 15 being positioned upstream from Lake Coleman and one positioned upstream from Hords Creek Lake. These structures, which partially control runoff from about 290 square miles, have a total flood control storage capacity of 63,194 acre-feet. 9 have been constructed within the portion of the Pecan Bayou watershed, between Lake Brownwood and the confluence of Willis Creek. 1 has been constructed on the headwaters of Willis Creek and 2 have been constructed in headwater areas of the South Willis Creek watershed. 9 have been constructed within the portion of the Pecan Bayou watershed, between the confluence of Willis and Blanket Creeks. 19 have been constructed on the Blanket Creek watershed.

Data in Table A-1 was taken from the SCS's "Status of Upstream Watershed Development - Texas". The listed drainage areas represent total watershed areas, rather than the amount directly affected by the SCS dams. Slight differences exist between these values and those determined during this study, which were based on 1:24,000 scale U.S. Geological Survey (USGS) topographic mapping. Turkey Creek is a major left-bank tributary of upper Pecan Bayou.

TABLE A-1

STATUS OF UPSTREAM WATERSHED DEVELOPMENT BY THE SOIL CONSERVATION SERVICE (SCS)

Watershed Number	Watershed Name	Drainage Area (acres)	(square miles)
501	Pecan Bayou, Upper	445760	696.5
502	Jim Ned Creek	477440	746.0
507	Brownwood Laterals	195200	305.0
515	Turkey Creek	59200	92.5
517	Blanket Creek	125440	196.0

Table A-2 includes a listing of the individual structures, in hydrologic order (more-or-less) beginning with the South Prong of Pecan Bayou watershed segment. Flood control storage values are based on the difference between storage amounts at the principal and emergency spillway crests, respectively. "PB", "JN", "BL","TC", and "BC" are abbreviations which represent the watersheds noted in the previous table. An asterisk (*) indicates an adjustment was made from SCS's published tables. The noted "Date of Plans" gives a relative indication of when each structure was implemented.

TABLE A-2

SUMMARY OF WATERSHED AREAS AFFECTED BY SCS FLOODWATER RETARDING STRUCTURES

Damsite Number	Affected Drainage Area		Flood Control Storage (ac-ft)	Date of Plans
	(acres)	(square miles)		
Pecan Bayou above confluence of Hog Creek:				
PB-1	7706	12.04	1785	05-66
PB-2	12890	20.14	5244	05-66
PB-3	1504	2.35	443	04-66
PB-4A	1523	2.38	430	04-66
PB-5	1280	2.00	349	04-66
PB-11-A	8422	13.16	2513	04-66
PB-6	9933	15.52	3008	05-66
PB-7	24282	37.94	5131 *	11-68
PB-9	3949	6.17	1247	05-67
PB-10	3936	6.15	1022	04-66
PB-12	11917	18.62	3505	04-66
PB-18A	7856	12.28	1869	02-68
PB-19	3968	6.20	1270	08-66
PB-20	1882	2.94	518	09-66
PB-21	1587	2.48	452	04-67
PB-22	2024	3.16	624	04-66
PB-23	1280	2.00	388	05-66
PB-24	8986	14.04	2718	03-71
PB-25	3002	4.69	832	04-73
TC-1-A	3981	6.22	881	03-63
TC-1-B	2837	4.43	636	04-63
TC-2	3492	5.46	1070	12-61
TC-3	704	1.10	220	12-61
TC-4	1124	1.76	386	04-62
TC-5	802	1.25	240	06-62
TC-6	4774	7.46	1664	07-62
TC-7	1702	2.66	519	07-62
TC-8	2522	3.94	757	01-62
TC-9	2954	4.62	1000	02-62
TC-10	3935	6.15	1223	02-62
TC-11A	1548	2.42	472	12-67
TC-12	2810	4.39	990	02-62
PB-26	1402	2.19	470	02-68
PB-34	1680	2.62	574	02-68
Totals of Pecan Bayou above confluence of Hog Creek:				
34 dams	154194	240.93	44450	
Pecan Bayou segment which includes Hog Creek:				
PB-30	3450	5.39	928	04-75
PB-31	640	1.00	237	11-69
PB-32	1619	2.53	605	02-71
PB-33	819	1.28	302	11-70
Totals of Pecan Bayou above confluence of Jim Ned Creek:				
38 dams	160722	251.13	46522	
Jim Ned Creek:				
JN-9	1980	3.09	685	05-62
JN-10	1486	2.32	446	05-62

JN-11	6341	9.91	2631	05-62
JN-12	10116	15.81	4841	01-62
JN-12A	6240	9.75	3076	05-62
JN-12C	3206	5.01	1327	03-61
JN-12E-1	19812	30.96	5000	07-64
JN-12F	3394	5.30	1470	04-61
JN-15	1260	1.97	321	05-59
JN-16	2660	4.16	674	04-59
JN-17	745	1.16	157	04-59
JN-17B-1	1884	2.94	571	02-68
JN-19	7200	11.25	2339	05-59
JN-20	7334	11.46	2532	05-59
JN-21	18510	28.92	5046	05-62
JN-22	3666	5.73	1539	05-62
JN-23	10381	16.22	5023	04-61
JN-5	904	1.41	273	04-61
JN-6	1700	2.66	548	04-61
JN-7	4640	7.25	1468	04-61
JN-8	3074	4.80	949	03-61
JN-24	6084	9.51	1988	03-61
JN-25	14776	23.09	5049	05-62
JN-25A	2774	4.33	845	01-62
JN-25B	1414	2.21	427	12-61
JN-37	4365	6.82	1373	04-73
JN-31	3240	5.06	964	11-63
JN-32	2870	4.48	849	04-61
JN-33	3670	5.73	1166	10-61
JN-34A	5357	8.37	1488	04-64
JN-35	1430	2.23	414	02-67
JN-36	990	1.55	298	02-67
JN-38A	600	0.94	38	04-76
JN-2	3516	5.49	1574	09-62
JN-3	2968	4.64	1113	08-61
JN-26A	9784	15.29	3073	03-65
JN-27	2686	4.20	802	04-61
JN-28	2710	4.23	817	05-66
Totals of Jim Ned Creek:				
38 dams	185767	290.26	63194	
Totals of Pecan Bayou above Lake Brownwood dam:				
76 dams	346489	541.39	109716	
Pecan Bayou segment between Lake Brownwood dam and U.S. Highway 67/377:				
BL-6	826 *	1.29 *	288	01-71
BL-10A	2029 *	3.17 *	823	03-69
BL-13	2400 *	3.75 *	850	01-67
BL-15	954 *	1.49 *	274	02-67
BL-14	666 *	1.04 *	220	01-67
BL-16A	2547 *	3.98 *	776	04-67
BL-11	627 *	0.98 *	207	01-67
BL-17	1190 *	1.86 *	380	03-67
Subtotals of abovementioned segment:				
8 dams	11238	17.56	3818	
Totals of Pecan Bayou above U.S. Highway 67/377:				
84 dams	357727	558.95	113534	
Adams Branch:				
BL-2A	1423	2.22	891	04-75
BL-2(REV)	1015	1.59	506	07-77

BL-1	1875 *	2.93 *	1083	04-76
BL-8	1805 *	2.82 *	852	05-67
Subtotals of Adams Branch:				
4 dams	6118	9.56	3332	
Totals of Pecan Bayou above confluence of Willis Creek:				
88 dams	363845	568.51	116866	
Willis Creek:				
BL-3	5888 *	9.20 *	3474	03-72
BL-4A	538 *	0.84 *	259	04-74
BL-4-B	730 *	1.14 *	372	04-74
Subtotals of Willis Creek:				
3 dams	7155	11.18	4105	
Totals of Pecan Bayou below confluence of Willis Creek:				
91 dams	371000	579.69	120971	
Pecan Bayou segment between Willis Creek and Blanket Creek:				
BL-19	3341 *	5.22 *	1125	03-66
BL-20	4064 *	6.35 *	1361	02-66
BL-21	2624 *	4.10 *	851	02-68
BL-25	1498 *	2.34 *	455	06-66
BL-26A-1	6114	9.55	1916	04-76
BL-22	1498 *	2.34 *	406	05-73
BL-23	1030 *	1.61 *	288	05-68
Subtotals of abovementioned segment:				
7 dams	20169	31.51	6402	
Totals of Pecan Bayou above Blanket Creek:				
98 dams	391169	611.2	127373	
Blanket Creek:				
BC-1	2317 *	3.62 *	811	09-64
BC-2-A	1939 *	3.03 *	542	02-68
BC-3	819 *	1.28 *	385	09-64
BC-4	621 *	0.97 *	311	08-64
BC-6	3206 *	5.01 *	967	12-64
BC-7	653 *	1.02 *	200	11-64
BC-8	1402 *	2.19 *	425	12-70
BC-10	1594 *	2.49 *	511	11-64
BC-11	3648 *	5.70 *	1144	01-71
BC-9	1485 *	2.32 *	480	05-67
BC-12	4851 *	7.58 *	1262	03-65
BC-13	2694 *	4.21 *	747	02-65
BC-14	2042 *	3.19 *	672	12-64
BC-15	2637 *	4.12 *	876	01-65
BC-16	1101 *	1.72 *	342	09-64
BC-20	2803 *	4.38 *	1014	09-64
BC-17A-1	9792 *	15.30 *	2880	03-66
BC-18	2758 *	4.31 *	823	10-64
BC-19	4902 *	7.66 *	1832	09-64
Subtotals of Blanket Creek:				
19 dams	51264	80.10	16224	
Totals of Pecan Bayou above State Highway 573:				
117 dams	442433	691.30	143597	

Most of these SCS reservoirs are expected to be "drawn-down" to principal spillway levels relatively quickly under normal conditions. However, under continually wet conditions, these reservoirs could be expected to store some floodwater, prior to a rainfall capable of producing flooding conditions further downstream. Under severe rainy conditions, it would be reasonable to assume that these reservoir pools could be much further into the "flood control" zones, perhaps up to the levels of the emergency spillways, prior to the occurrence of another significant, flood-producing storm. Even in this case, they tend to retard the flood wave enough to provide a much reduced peak discharge further downstream, in comparison to that of the previous, totally uncontrolled watershed condition.

STREAMFLOW AND RESERVOIR STORAGE GAGING STATIONS

The USGS has, at times, maintained streamflow and/or reservoir pool level recording gages at several points within the watershed. A summary is provided in Table A-3.

TABLE A-3

U.S. GEOLOGICAL SURVEY (USGS) GAGING STATIONS

Name	ID Number	Recorded Variable	Period of Record
Lake Clyde near Clyde	8140600	Reservoir Storage	Jan.'70 - Sep.'85
Pecan Bayou near Cross Cut	8140700	Mean Daily Flow	Apr.'68 - Dec.'78
Pecan Bayou near Cross Cut	8140700	Annual Peak Flow	Apr.'68 - Dec.'78
Jim Ned Creek near Coleman	8140800	Mean Daily Flow	Mar.'65 - Sep.'80
Jim Ned Creek near Coleman	8140800	Annual Peak Flow	Mar.'65 - Sep.'80
Hords Creek Lake near Valera	8141000	Reservoir Storage	Apr.'48 - present
McCall Branch near Coleman	8141100	Annual Peak Flow	'66 - '74
Hords Creek near Valera	8141500	Mean Daily Flow	Apr.'47 - Dec.'90
Hords Creek near Valera	8141500	Annual Peak Flow	Apr.'47 - Dec.'90
Hords Creek at Coleman	8142000	Mean Daily Flow	Oct '40 - Sep.'70
Hords Creek at Coleman	8142000	Annual Peak Flow	Oct.'40 - present
Brown County WID #1 Canal	8142500	Mean Daily Flow	Mar.'50 - Mar.'83
Lake Brownwood near Brownwood	8143000	"Monthly" Storage	Jul.'33 - May '41
Lake Brownwood near Brownwood	8143000	"Monthly" Storage	Nov.'44 - Sep.'47
Lake Brownwood near Brownwood	8143000	Reservoir Storage	Oct.'47 - Sep.'86
Pecan Bayou at Brownwood	8143500	Mean Daily Flow	Oct.'23 - Sep.'83
Pecan Bayou at Brownwood	8143500	Annual Peak Flow	Oct.'23 - Sep.'83
Pecan Bayou near Mullin	8143600	Mean Daily Flow	Oct.'67 - present
Pecan Bayou near Mullin	8143600	Annual Peak Flow	Oct.'67 - present

The "Lake Brownwood", "Pecan Bayou at Brownwood", and "Pecan Bayou near Mullin" gage records were analyzed statistically during this study. Even though record lengths would appear to be adequate for developing reasonable frequency relationships, there are several weaknesses which should be noted.

Lake Brownwood experienced probably its greatest inflow in July 1932, while the embankment was still under construction. The resultant peak pool elevation of about 1427 feet NGVD (2 feet over the emergency spillway crest) has since been exceeded in at least 13 water years, but it might have been the flood-of-record, had the reservoir been near conservation pool level at the onset of the event. During that event, the principal spillway gates were opened to help relieve the hydrostatic pressure on the incomplete embankment and the reservoir level was substantially lowered. Then, in June 1934, one of the two principal spillway gates was partially opened, to allow passage of flow to assist the rice growing industry in the lower Colorado River Basin. Two days later the operators were unable to successfully close the gate, and by early September the reservoir had been emptied. The gates were repaired in October and the lake began filling again, during the Spring of 1935. The conservation pool level was again approached by May, and a significant flood in June resulted in a peak pool elevation of about 1428 feet NGVD

(3 feet over the emergency spillway crest). The peak pool elevation for that water year, 1428.9 feet NGVD, was reached on 10 September. "End-of-month" readings available through water year 1947 indicate that the pool level exceeded the emergency spillway crest in most of those years, but the stage of the September 1935 flood was not surpassed.

A continual gaging period lasted from water year 1948 through water year 1986. During this period, annual maximum pool elevations ranged considerably, from 1419.5 to 1430.9 feet NGVD. The emergency spillway was overtopped in only 25 of these 39 water years. Information provided by the Brown County WID Number 1 indicates that peak pool elevations of about 1429.8 and 1432.6 feet NGVD were reached on 27 April 1990 and 21 December 1991, respectively, the latter of which represents the maximum reservoir level obtained to date. Table A-4 provides a summary of annual maximum pool elevations during the period of **continual** (systematic) record. The "Flood Frequency Analysis" (FFA) program was used to rank the annual events and to assign the respective median probability plotting position, as shown in the right-hand half of Table A-4.

TABLE A-4

SYSTEMATIC RECORD OF ANNUAL MAXIMUM POOL ELEVATIONS ON LAKE BROWNWOOD

EVENTS ANALYZED				ORDERED EVENTS			
MONTH	DAY	YEAR	POOL ELEVATION	RANK	WATER YEAR	POOL ELEVATION	MEDIAN PLOTTING POSITION
1	15	1948	1422.6	1	1956	1430.9	1.78
5	16	1949	1426.1	2	1951	1429.9	4.31
10	28	1949	1423.3	3	1986	1429.4	6.85
6	12	1951	1429.9	4	1957	1428.9	9.39
6	9	1952	1422.9	5	1959	1428.9	11.93
7	19	1953	1425.0	6	1968	1428.8	14.47
4	14	1954	1426.0	7	1965	1428.1	17.01
6	16	1955	1427.1	8	1982	1427.6	19.54
5	2	1956	1430.9	9	1972	1427.2	22.08
5	26	1957	1428.9	10	1975	1427.2	24.62
10	15	1957	1426.9	11	1955	1427.1	27.16
7	21	1959	1428.9	12	1961	1427.0	29.70
10	5	1959	1425.3	13	1958	1426.9	32.23
6	6	1961	1427.0	14	1963	1426.4	34.77
7	27	1962	1425.3	15	1949	1426.1	37.31
5	31	1963	1426.4	16	1954	1426.0	39.85
4	25	1964	1425.3	17	1971	1426.0	42.39
5	17	1965	1428.1	18	1969	1425.9	44.92
9	18	1966	1425.6	19	1979	1425.8	47.46
10	1	1966	1423.9	20	1970	1425.7	50.00
1	22	1968	1428.8	21	1966	1425.6	52.54
5	10	1969	1425.9	22	1964	1425.3	55.08
12	30	1969	1425.7	23	1962	1425.3	57.61
9	26	1971	1426.0	24	1960	1425.3	60.15
10	20	1971	1427.2	25	1974	1425.0	62.69

5	1	1973	1420.4	26	1953	1425.0	65.23
9	29	1974	1425.0	27	1978	1424.3	67.77
10	31	1974	1427.2	28	1967	1423.9	70.30
10	12	1975	1422.2	29	1980	1423.3	72.84
5	14	1977	1419.9	30	1950	1423.3	75.38
9	12	1978	1424.3	31	1952	1422.9	77.92
6	26	1979	1425.8	32	1948	1422.6	80.46
10	2	1979	1423.3	33	1983	1422.5	82.99
6	10	1981	1420.6	34	1985	1422.5	85.53
6	27	1982	1427.6	35	1976	1422.2	88.07
6	11	1983	1422.5	36	1981	1420.6	90.61
10	12	1983	1419.5	37	1973	1420.4	93.15
3	31	1985	1422.5	38	1977	1419.9	95.69
6	3	1986	1429.4	39	1984	1419.5	98.22

These points were plotted on arithmetic versus normal-probability paper in order to get a feel for the pool elevation versus frequency relationship. See Plate A-3. It should be noted that this systematic record does **not** include the major events of 1932, 1990, or 1991, not to mention historic estimates for the known floods which occurred in 1869, 1875, 1900, 1908, and 1915, among others. Additionally, the array shown on Plate A-3 does not consider partial duration adjustments for the more frequent end of the curve.

The frequency curve would appear to "dip" below the conservation pool level (1425 feet NGVD elevation). This is due to the fact that the systematic record includes 14 of 39 total points below that level. While this is a believable scenario, considering routine drawdowns resulting from municipal/ agricultural water releases and normal evaporation patterns, it does not properly account for the flood risk associated with extended wet periods, especially for the assessment of the more rare events.

Major floods are noted to have occurred on Pecan Bayou at Brownwood, in 1869, 1875, 1900, 1908, and 1915. Other significant, recorded events include those on 18 May 1918 (28,000 cfs), 20 May 1928 (18,300 cfs), 13 May 1930 (18,200 cfs), 14 October 1930 (31,600 cfs), and 13 October 1931 (20,900 cfs). These were all prior to the existence of Lake Brownwood. No attempt was made to convert those peak discharge values to ones which would have resulted with Lake Brownwood in full operation. Perhaps the most significant event of that category would be the flood of 3 July 1932, mentioned earlier in this narrative. According to USGS records:

> "Flood of July 3, 1932, probably the greatest, reached a discharge of about 235,000 cfs as it entered Lake Brownwood (computed from rate of change in contents in the partially completed lake); data furnished by engineers of Brown County Water Improvement District No. 1."

The 1932 flood hydrograph was significantly attenuated by the partially completed Lake Brownwood dam. The peak flow below the dam was estimated at about 17,000 cfs. Acting as a flood control reservoir, Lake Brownwood effectively saved the City of Brownwood from very severe flood damages.

Table A-5 provides a summary of annual maximum discharges during the period of systematic record since deliberate impoundments within Lake Brownwood were initiated in July 1933. The "FFA" program was used to rank the annual events and to assign the respective median probability plotting position, as shown in the right-hand half of Table A-5.

TABLE A-5

SYSTEMATIC RECORD OF ANNUAL PEAK DISCHARGES ON PECAN BAYOU AT BROWNWOOD

EVENTS ANALYZED				ORDERED EVENTS			
MONTH	DAY	YEAR	FLOW	RANK	WATER YEAR	FLOW	MEDIAN PLOTTING POSITION
6	28	1934	3620	1	1956	26500	1.39
9	10	1935	11600	2	1951	20200	3.37
9	28	1936	16500	3	1941	19800	5.36
6	6	1937	2580	4	1959	18000	7.34
7	26	1938	5290	5	1957	17400	9.33
6	20	1939	9700	6	1936	16500	11.31
8	17	1940	5700	7	1968	15600	13.29
5	4	1941	19800	8	1943	12300	15.28
5	20	1942	9050	9	1965	11800	17.26
10	18	1942	12300	10	1935	11600	19.25
5	1	1944	2560	11	1945	11000	21.23
7	8	1945	11000	12	1939	9700	23.21
9	14	1946	2070	13	1942	9050	25.20
11	3	1946	790	14	1949	8780	27.18
12	7	1947	1710	15	1960	8760	29.17
5	17	1949	8780	16	1958	7400	31.15
10	24	1949	580	17	1955	7240	33.13
6	12	1951	20200	18	1975	7200	35.12
5	23	1952	2690	19	1972	6990	37.10
4	28	1953	4760	20	1961	6600	39.09
10	4	1953	4630	21	1940	5700	41.07
9	23	1955	7240	22	1938	5290	43.06
5	2	1956	26500	23	1982	4780	45.04
4	26	1957	17400	24	1953	4760	47.02
10	15	1957	7400	25	1964	4700	49.01
7	22	1959	18000	26	1954	4630	50.99
10	4	1959	8760	27	1963	4430	52.98
6	6	1961	6600	28	1980	4420	54.96
9	8	1962	1630	29	1967	3650	56.94
5	28	1963	4430	30	1934	3620	58.93
4	24	1964	4700	31	1979	2900	60.91
5	17	1965	11800	32	1971	2730	62.90
6	18	1966	2580	33	1952	2690	64.88
9	15	1967	3650	34	1974	2640	66.87
1	22	1968	15600	35	1937	2580	68.85
5	10	1969	2430	36	1966	2580	70.83
6	2	1970	2210	37	1944	2560	72.82
9	26	1971	2730	38	1969	2430	74.80
10	20	1971	6990	39	1970	2210	76.79
4	24	1973	196	40	1946	2070	78.77

9	21	1974	2640	41	1948	1710	80.75
11	1	1974	7200	42	1962	1630	82.74
4	20	1976	419	43	1947	790	84.72
3	28	1977	134	44	1950	580	86.71
5	11	1978	130	45	1981	479	88.69
6	26	1979	2900	46	1976	419	90.67
5	14	1980	4420	47	1983	398	92.66
5	16	1981	479	48	1973	196	94.64
6	27	1982	4780	49	1977	134	96.63
6	5	1983	398	50	1978	130	98.61

These points were plotted on logarithmic versus normal-probability paper in order to get a feel for the discharge versus frequency relationship. See Plate A-4. It should be noted that this systematic record does **not** include the major events of 1918, 1928, 1930, 1931, 1932, 1986, 1990, or 1991, not to mention historic estimates for the known floods which occurred in 1869, 1875, 1900, 1908, and 1915, among others. Additionally, the array shown on Plate A-4 does not consider partial duration adjustments for the more frequent end of the curve.

As was the case for the Lake Brownwood pool elevation versus frequency curve, the systematic record does not properly account for the flood risk associated with extended wet periods, especially for the assessment of the more rare events. Table A-6 provides a summary of standard output from the "FFA" program run.

TABLE A-6

FLOOD FREQUENCY ANALYSIS PROGRAM OUTPUT FOR GAGESITE: PECAN BAYOU AT BROWNWOOD

COMPUTED DISCHARGE (cfs)	EXPECTED DISCHARGE (cfs)	ANNUAL EXCEEDANCE PROBABILITY	EFFECTIVE RECURRENCE INTERVAL (years)	5 PERCENT CONFIDENCE LIMIT (cfs)	10 PERCENT CONFIDENCE LIMIT (cfs)
62700	69700	0.002	500	121000	38300
51400	56000	0.005	200	95500	32100
43000	46300	0.010	100	77600	27400
34900	37100	0.020	50	60900	22800
24800	25900	0.050	20	41000	16700
17700	18200	0.100	10	27900	12300
11300	11500	0.200	5	16800	8140
4220	4220	0.500	2	5760	3110
1310	1270	0.800		1810	888
655	622	0.900		955	407
355	326	0.950		551	201
102	83	0.990		183	46

SYSTEMATIC STATISTICS

LOG-TRANSFORMED FLOW (log cfs)		NUMBER OF EVENTS	50
MEAN	3.5687	HISTORIC EVENTS	0
STANDARD DEVIATION	0.5665	HIGH OUTLIERS	0
COMPUTED SKEW	-0.9541	LOW OUTLIERS	0
REGIONAL SKEW	0.0000	ZERO OR MISSING	0
ADOPTED SKEW	-0.6001	SYSTEMATIC EVENTS	50

Historic flooding information at the gagesite "Pecan Bayou near Mullin" was not readily available during this study. However, systematic records have been kept since water year 1968. Table A-7 provides a summary of annual maximum discharges during the period of systematic record. The "FFA" program was used to rank the annual events and to assign the respective median probability plotting position, as shown in the right-hand half of Table A-7.

TABLE A-7

SYSTEMATIC RECORD OF ANNUAL PEAK DISCHARGES ON PECAN BAYOU NEAR MULLIN

EVENTS ANALYZED				ORDERED EVENTS			
MONTH	DAY	YEAR	FLOW	RANK	WATER YEAR	FLOW	MEDIAN PLOTTING POSITION
1	23	1968	13700	1	1990	38300	2.76
5	7	1969	3240	2	1992	33000	6.69
6	1	1970	2800	3	1989	15400	10.63
8	1	1971	5530	4	1968	13700	14.57
10	21	1971	5820	5	1986	13400	18.50
4	24	1973	1310	6	1988	11200	22.44
10	13	1973	6000	7	1985	7760	26.38
11	2	1974	6320	8	1991	7380	30.31
7	16	1976	1820	9	1977	6700	34.25
3	27	1977	6700	10	1975	6320	38.19
8	3	1978	1690	11	1974	6000	42.13
6	27	1979	2620	12	1972	5820	46.06
5	15	1980	4230	13	1971	5530	50.00
9	1	1981	2030	14	1982	5370	53.94
6	28	1982	5370	15	1987	5160	57.87
6	5	1983	4270	16	1983	4270	61.81
3	23	1984	1520	17	1980	4230	65.75
6	6	1985	7760	18	1969	3240	69.69
6	8	1986	13400	19	1970	2800	73.62
5	31	1987	5160	20	1979	2620	77.56
6	1	1988	11200	21	1981	2030	81.50
6	11	1989	15400	22	1976	1820	85.43
4	27	1990	38300	23	1978	1690	89.37
9	21	1991	7380	24	1984	1520	93.31
12	22	1991	33000	25	1973	1310	97.24

These points were plotted on logarithmic versus normal-probability paper in order to get a feel for the discharge versus frequency relationship. See Plate A-5. It should be noted that this systematic record does **not** include major historic events. Additionally, the array shown on Plate A-5 does not consider partial duration adjustments for the more frequent end of the curve.

It is possible that the systematic record does not properly account for the flood risk associated with extended wet periods, especially for the assessment of the more rare events, with regards to outflows from both Lake Brownwood and the numerous SCS floodwater retarding structures. Table A-8 provides a summary of standard output from the "FFA" program run.

TABLE A-8

FLOOD FREQUENCY ANALYSIS PROGRAM OUTPUT FOR GAGESITE: PECAN BAYOU NEAR MULLIN

COMPUTED DISCHARGE (cfs)	EXPECTED DISCHARGE (cfs)	ANNUAL EXCEEDANCE PROBABILITY	EFFECTIVE RECURRENCE INTERVAL (years)	5 PERCENT CONFIDENCE LIMIT (cfs)	10 PERCENT CONFIDENCE LIMIT (cfs)
92800	140000	0.002	500	238000	50700
66700	90200	0.005	200	156000	38500
51100	64300	0.010	100	110000	30800
38300	45400	0.020	50	76600	24200
25200	27900	0.050	20	45000	16900
17500	18700	0.100	10	28700	12300
11500	11800	0.200	5	17100	8400
5280	5280	0.500	2	7130	3890
2550	2490	0.800		3490	1710
1780	1700	0.900		2520	1100
1340	1240	0.950		1960	772
799	683	0.990		1260	402

SYSTEMATIC STATISTICS

LOG-TRANSFORMED FLOW (log cfs)		NUMBER OF EVENTS	25
MEAN	3.7377	HISTORIC EVENTS	0
STANDARD DEVIATION	0.3883	HIGH OUTLIERS	0
COMPUTED SKEW	0.4083	LOW OUTLIERS	0
REGIONAL SKEW	0.0000	ZERO OR MISSING	0
ADOPTED SKEW	0.2370	SYSTEMATIC EVENTS	25

PRIOR STUDIES

Detailed descriptions of many of the following studies are presented in the main feasibility report narrative. The information was collected and arranged by the Planning Study Manager (Technical Manager).

USACE General Investigation (GI) Studies:

a. Report from the Chief of Engineers on Preliminary Examination of Colorado River, Texas, with a View to the Control of its Floods, April 3, 1930 (House Document No. 361, 71st Congress, 2nd Session)

b. Report on Survey of Pecan Bayou, Texas, for Flood Control and Allied Purposes, March 1939 (House Document No. 370, 76th Congress, 1st Session.

c. Definite Project Report on Hords Creek Reservoir, Hords Creek near Coleman, Texas, Colorado River Basin, February 1946.
d. Review of Reports - 1948 (unofficial).
e. The Master Plan for Recreation and Land Use, Hords Creek Dam and Reservoir near Coleman, Texas, May 1950.
f. Review of Reports on Pecan Bayou Watershed, Colorado River Basin, Texas - October 1963.
g. House Document Number 350, 90th Congress, 2nd Session, July 8, 1968, Pecan Bayou, Texas.
h. Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase I - Plan Formulation, April 1975.
i. Revised Plan of Study, Feasibility Report for Water Resources Development, Colorado River and Tributaries, Texas, Colorado River Basin, Texas, June 1975.
j. Navigability Study, Colorado River, Tributaries and Lakes, Colorado River Basin, Texas (River Mile 290.1 to 890.0), February 1975.
k. Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 1, General, Phase II - Project Design, June 1976.
l. Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 4, Availability of Construction Materials, June 1976.
m. Lake Brownwood Modification, Pecan Bayou, Colorado River Basin, Texas, Design Memorandum Number 5, Real Estate - Lands For Construction Area, July 1976.
n. A Final Supplement to the Final Environmental Statement, Lake Brownwood Modification, Pecan Bayou Watershed, Colorado River Basin, Texas - March 1977.
o. Status Report - Colorado River Basin, Texas - September 1987.

Federal Emergency Management Agency(FEMA) Flood Insurance Studies (FIS's):

The counties of Brown, Comanche, Mills, and Taylor, and the cities/towns of Blanket, Brownwood, Clyde, Coleman, and Early are active participants in the National Flood Insurance Program (NFIP). The Brownwood FIS has an effective date of 6 July 1982. The hydrologic and hydraulic analyses for that study were performed by Bovay Engineers, Inc. Their work was completed in July 1979. According to the published FIS report, "Peak discharges of 10-, 50- and 100-year floods for all the flooding sources, except the Tributary of South Willis Creek, studied in detail were developed by the SCS. The 500-year peak discharge for Pecan Bayou was extrapolated by using the standard Log Pearson Type III method as outlined by the Water Resources Council. Peak discharge estimates for the remaining flooding sources were generated with regional regression equations documented in the publication, Technique for Estimating with Magnitude and Frequency of Floods in Texas, together with the standard Log Pearson Type III method." The published FIS summary of peak discharges is shown in Table A-9.

U.S. Study Commission - Texas:

a. Runoff - Colorado River Basin, August 1960.
b. Upstream Flood Prevention and Water Resources Development in the Colorado River Basin, January 1961.
c. The Report of the U.S. Study Commission - Texas, The Eight Basins,

March 1962.

U.S. Department of the Interior:
Reservoir Operation in Texas - June 1985.

TABLE A-9

SUMMARY OF PEAK DISCHARGES FROM THE PUBLISHED FLOOD INSURANCE STUDY (FIS)

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq.mi.)	PEAK DISCHARGES			
		10-YEAR (cfs)	50-YEAR (cfs)	100-YEAR (cfs)	500-YEAR (cfs)
PECAN BAYOU					
At Eastern City Limit	1641	21460	44150	56900	95500
ADAMS BRANCH					
Below Belle Plain Avenue	14.8	2513	4000	4743	10500
Below Beaver Avenue	9.7	1934	2950	3464	8100
Below Epley Avenue	9.4	1843	2875	3358	7900
Above Cordell Street	9.1	1758	2750	3236	7700
Below Coleman Avenue	8.4	1412	2265	2693	7350
Above Atchison, Topeka & Sante Fe Railroad	7.6	1151	1900	2283	6800
TOM WILLIAMS CREEK					
Below US Highway 67	4.7	852	1400	1670	5050
Above Walnut Street	4.0	520	900	1089	4525
Above Hickory Street	3.6	429	730	886	4210
WILLIS CREEK					
Below Eastern City Limits	23.8	2107	3640	4589	10460
Below Austin Avenue	23.4	2013	3525	4338	10430
Below South Willis Creek	22.9	1949	3340	4091	10410
Below F.M. 3064	11.0	521	880	1087	8700
SOUTH WILLIS CREEK					
Below Tributary of South Willis Creek	10.7	1313	2260	2779	8550
Below Stephen Austin Drive	9.3	1267	2050	2674	7850
TRIB. OF SOUTH WILLIS CREEK					
Below Indian Creek Drive	1.4	637	1182	1456	2245

Reports by State Agencies:

a. A Plan for Meeting the 1980 Water Requirements for Texas - 1961.
b. Occurrence and Quality of Ground Water in Brown County, Texas, Report 46, May 1967, by the Texas Water Development Board.
c. The Texas Water Plan, by the Texas Water Development Board.
d. Water For Texas, 1984, by the Department of Water Resources.
e. Water For Texas, Today and Tomorrow, 1990, by the Department of Water Resources.
f. The State of Texas Water Quality Inventory, 11th Edition, August

1992, by the Texas Water Commission.

g. Water For Texas, Today and Tomorrow, 1992, by the Department of Water Resources.

Reports by Engineering Firms, for the Brown County WID Number 1:

a. Hydrologic Study of Lake Brownwood and the Pecan Bayou Watershed, March 1965, by Freese, Nichols and Endress.
b. Report to the Brown County Water Improvement District Number 1 on Investigation of Lake Brownwood Dam, November 1979, by Freese and Nichols, Inc.

FLOOD HISTORY

In general, the major storms of this area are produced by frontal-type activity occurring mainly in the spring and fall, but occasionally at other times of the year. These storms are usually intense localized thunderstorms resulting in significant rainfall amounts.

Prior to the existence of Lake Brownwood, significant flood events are noted to have occurred in 1869, 1875, 1900, 1908, 1915, and on 18 May 1918, 20 May 1928, 13 May 1930, 14 October 1930, and 13 October 1931. Since the initiation of construction on Lake Brownwood, the most significant flood events have been those occurring on 3 July 1932, 28 September 1936, 4 May 1941, 18 October 1943, 12 June 1951, 2 May 1956, 26 April 1957, 22 July 1959, 22 January 1968, 3 June 1986, 27 April 1990, and 21 December 1991. Systematic and those available historic records are provided earlier in this narrative.

CLIMATOLOGY

The following narrative section was taken from the U.S. Department of Commerce, Environmental Science Services Administration's Climatological Data Summary for Brownwood, as revised in February 1968.

> The climate of Brownwood is subtropical with dry winters and humid summers. Mean total precipitation is 27.20 inches annually. There is a wide annual range in temperature, and air mass changes are frequent during the cool season. Prevailing winds are south to south-southeasterly throughout the year, although northerly winds are frequent in winter.
>
> Winter temperatures are mild with only about four days during the season, on an average, when the maximum temperature fails to rise above freezing. Rapid drops in temperature occur when polar and arctic air masses plunge southward out of Canada. Periods of very cold weather are short however, rarely lasting longer than two or three days. Periods of fair, mild weather occur often in January and February. The lowest temperature on record (since 1890) is -2 degrees Fahrenheit, and occurred in January 1940.
>
> Hot daytime temperatures in summer are broken by thunderstorm activity on an average of five times a month. The highest temperatures are usually associated with fair skies, southwesterly winds and dry air. The record high temperature at Brownwood (since 1890) is 113 degrees Fahrenheit, and occurred in July 1925.
>
> Precipitation falls mostly as thundershowers. These occur with greatest frequency during May and June, contributing to a peak rainfall period during late spring and early summer. The anticyclonic atmospheric circulation over Texas in summer results in a relatively dry period in late summer, followed by a secondary

peak in rainfall in early fall. High intensity rains of short duration, producing rapid runoff, may occur anytime during the year.

Snowfall in the area is almost negligible. A few exceptionally heavy snowfalls, such as the eight-inch fall in February 1966, create a bias in the mathematical mean for long periods of years so that this statistic is usually a poor estimate of expected snowfall. In January 1919, a record fall of 17 inches occurred. Ordinarily snow remains on the ground no longer than a few hours.

The growing season (freeze free period) at Brownwood averages 247 days. The average date of the last freeze in the spring is March 16, while the average date of the first freeze in the fall is November 19. Low temperatures are very sensitive to variations in topography, wind, vegetative cover, soil type and condition; therefore, significant departures from these mean values are likely to be found, not only in the surrounding rural area, but within the city limits of Brownwood.

Mean annual relative humidity is about 78 percent at 6:00 a.m., 51 percent at noon, and 45 percent at 6:00 p.m., Central Standard Time. Seasonal variations are small. The area receives about 65 percent of the total possible sunshine annually. Mean annual lake evaporation is estimated at 64 inches.

In summary, the Brownwood climate is subtropical with mild winters favorable for outdoor work or recreation the year round. Daytime temperatures are rather hot in summer. Spring and fall are the most delightful seasons.

Official climatic data recorded at Brownwood, and compiled by Hydrosphere Data Products, Inc. was used to develop the remainder of this climatologic summary. Based on records covering the period January 1947 through May 1992, precipitation amounts are typically distributed through the year as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1.50	1.69	1.68	2.75	3.74	3.28	1.61	1.81	2.89	2.81	1.39	1.54	26.92

Daily temperatures, in degrees Fahrenheit, have typically ranged from highs in the middle to upper 90's in July-August, to lows in the upper 20's to lower 30's in January. Daily precipitation extremes include: 11.49 inches, on 26 April 1990; 6.60 inches, on 5 October 1959; and 5.90 inches, on 1 June 1988. The temperature extremes are: 111 degrees Fahrenheit, on 7 August 1964; and -6 degrees Fahrenheit, on 23 December 1989. The maximum calendar month precipitation was 14.66 inches in April 1990, closely followed by the 12.90 inches in June 1959. The maximum calendar year precipitation was 45.97 inches in 1990, while the minimum was 12.83 inches in 1954.

Precipitation data is also available, often to a limited extent, at other stations within and adjacent to the Pecan Bayou watershed. Some of these include: Lawn, Lake Abilene, Abilene, Baird, Putnam, McDonald Store, Cross Plains, Burkett, Byrds, Rising Star, Comanche, Blanket, Priddy, Mullin, Goldthwaite, Winchell, Trickham, Heath Farm, Santa Anna, Coleman, Hords Creek Dam, Talpa, Novice, and Silver Valley. Of these stations, however, only those at Abilene, Cross Plains, Winchell, and Santa Anna have been operated as hourly recording gages.

DETERMINATION OF PERCENT SAND

The computation of percent sand was based on a comparison of the permeabilities of the major soil types in the study area watersheds with those of the Houston Black and Crosstell Series soils.

The Houston Black soil series consists of moderately well-drained, deep, cyclic, clayey soils. This series formed in alkaline, marine clay, and material weathered from shale. Land slopes range from 1 to 4 percent. Its permeability is less than 0.06 inches per hour (iph). This soil is the predominant series found in the watersheds used to develop the Blackland Prairie Clay Urbanization Curves, Plate A-6. It has a percent sand value of zero, for use with these urbanization curves.

The Crosstell soil series consists of moderately well-drained, deep, loamy soils on uplands that formed in shaley and clayey sediment containing thin strata of weakly cemented sandstone. Land slopes range from 1 to 5 percent. Its permeability is in the range between 0.5 and 2.0 iph. This soil is the predominant series found in the watersheds used to develop the Cross Timber Sandy Loam Urbanization Curves, Plate A-7. It has a percent sand value of 100, for use with these urbanization curves. Some soils are from series with higher permeability rates than that of the Crosstell Series. Those having permeability rates ranging between 2 and 6 iph are assigned a 133 percent sand value, and those having permeability rates greater than 6 iph are assigned a 167 percent sand value.

Percent sand values for soil types with permeability rates between those for clayey and sandy soils were linearly interpolated. After the percent sand for each soil type was determined, a weighting was applied by multiplying the appropriate percent sand value for each soil type by the percent of the subarea covered by that soil type. In any instances where weighted percent sand values over 100 percent were computed, a 100 percent sand value was adopted, to be consistent with the derivation of the urbanization curves.

The SCS Soil Surveys for each of the counties within the Pecan Bayou watershed were consulted to determine general soil types, and their respective permeability rates. After careful consideration of this and additional factors affecting the amount and rate of surface runoff, and efficiency of the stream network systems, it was determined that these watersheds would react similarly to those watersheds used in the development of the Cross Timber Sandy Loam Urbanization Curves; therefore, each subarea was assigned a "percent sand" value of 100.

DETERMINATION OF URBANIZATION AND IMPERVIOUSNESS

Values of percent urbanization and imperviousness were developed for each subbasin. Urbanization is the percentage of a subbasin which has been developed and improved with channelization and/or a stream collection network. It affects the Snyder's unit hydrograph "time to peak" (Tp) value. Imperviousness is the percentage of a subbasin which is covered with impervious material and is hydraulically connected to the drainage network. It affects the volume of rainfall lost through interception and infiltration.

The urbanization and imperviousness values for this study are based on USDA aerial photography, USGS topographic quadrangle maps, and additional information obtained during site visits. Upstream from Brownwood, the Pecan Bayou watershed is rural, except for development around Lake Brownwood and that at several small, scattered communities. The specific watersheds of Willis Creek and South Willis Creek are distinctly rural in the headwater areas above the city, but very highly developed within the city. In addition to the urbanized areas which contain various percentages of impervious surface materials, those areas normally inundated by major reservoirs and the numerous USDA Soil Conservation Service reservoirs and farm ponds were also treated as fully impervious to the passage of rainfall.

DEVELOPMENT OF DISCHARGE VERSUS FREQUENCY RELATIONSHIPS

Rainfall for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year frequency storms and the Standard Project storm were developed using data from the following sources:

USDC Weather Bureau Technical Paper No. 40 (TP-40): "Rainfall Frequency Atlas of the United States", dated May 1961.

USDC NOAA Technical Memorandum NWS HYDRO-35: "Five- to 60-minute Precipitation Frequency for the Eastern and Central United States", dated June 1977.

Civil Engineer Bulletin No. 52-8: "Standard Project Flood Determinations", EM 1110-2-1411, Department of the Army, Office of the Chief of Engineers, dated 26 March 1952.

Rainfall for the 500-year frequency storm was computed by extrapolation of data from the previously mentioned sources. Table A-10 summarizes the hypothetical point rainfalls for the Brownwood area. The rainfall for each duration-frequency related storm was adjusted to the critical drainage area size at each discharge location based upon Figure 15 of TP-40, "Depth-Area-Duration Curves". A mass rainfall curve was then generated from the adjusted point rainfall values for each frequency, interpolated into incremental rainfall amounts, and distributed at 15-minute time intervals. Table A-11 presents a sample of the 100-year frequency rainfall distribution for an 8.53-square mile subbasin.

TABLE A-10

HYPOTHETICAL STORM DATA (inches)

ANNUAL EXCEEDANCE PROBABILITY	EFFECTIVE RECURRENCE INTERVAL (years)	STORM DURATION (hours)										
		0.25	0.5	1	2	3	6	12	24	48	72	96
	1	0.63	0.74	0.95	1.58	1.75	2.15	2.54	2.875	3.40	3.7	4.0
0.500	2	0.99	1.37	1.77	2.01	2.25	2.69	3.19	3.715	4.23	4.6	4.9
0.200	5	1.18	1.72	2.29	2.77	3.045	3.655	4.37	5.085	5.50	5.9	6.4
0.100	10	1.32	1.97	2.64	3.29	3.61	4.365	5.21	5.97	6.65	7.1	7.6
0.050	25	1.52	2.32	3.15	3.845	4.275	5.185	6.11	7.09	8.05	8.6	9.1
0.020	50	1.68	2.59	3.54	4.55	4.83	5.72	6.90	8.05	9.10	9.8	10.45
0.010	100	1.84	2.87	3.93	4.875	5.40	6.53	7.81	9.10	10.45	11.0	11.5
0.002	500	2.29	3.63	4.67	6.58	7.29	8.82	10.54	12.29	14.11	14.85	15.53

SPF RAINFALL = 14.1 inches (over 200 square miles)

TABLE A-11

100-YEAR FREQUENCY RAINFALL DISTRIBUTION

BROWNWOOD - G.I. RECON - AUGUST 1993
100 YEAR STORM CENTERING ON
SUBAREA 1 - WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#3
MASS RAINFALL AND AREA REDUCTION FACTORS
DRAINAGE AREA = 8.53 SQUARE MILES

DURATION (hours)	POINT RAINFALL (inches)	REDUCTION FACTOR	EFFECTIVE RAINFALL (inches)
0.25	1.8400	0.8365 *	1.5391
0.5	2.8651	0.9128	2.6153
1	3.9300	0.9505	3.7355
2	4.8750	0.9654	4.7062
3	5.4000	0.9693	5.2344
6	6.5300	0.9809	6.4050
12	7.8100	0.9825	7.6733
24	9.1000	0.9851	8.9640

* This reduction factor was not available from Figure 15 of TP-40. The final 15-minute rainfall is actually determined within the SWFHYD program based on the mathematical relationship between the 15-, 30-, and 60-minute values, as stated In HYDRO-35. The 0.8365 reduction factor listed above was simply "back-solved".

			RAINFALL CURVES		
TIME (hour)	FLOOD HYDROGRAPH (cfs)	UNIT HYDROGRAPH (cfs)	RAIN (inches)	LOSS (inches)	EXCESS (inches)
0:15	0	0	0.0168	0.0167	0.0002
0:30	0	10	0.0171	0.0169	0.0002
0:45	0	113	0.0177	0.0175	0.0002
1:00	0	408	0.0180	0.0178	0.0002
1:15	0	846	0.0186	0.0184	0.0002
1:30	0	1291	0.0190	0.0188	0.0002
1:45	1	1634	0.0196	0.0194	0.0002
2:00	1	1834	0.0200	0.0198	0.0002
2:15	1	1894	0.0207	0.0205	0.0002
2:30	2	1846	0.0211	0.0209	0.0002
2:45	2	1724	0.0219	0.0217	0.0002
3:00	2	1561	0.0223	0.0221	0.0002
3:15	3	1382	0.0232	0.0229	0.0002
3:30	3	1201	0.0236	0.0234	0.0002
3:45	3	1030	0.0246	0.0243	0.0002
4:00	3	875	0.0251	0.0248	0.0003
4:15	4	737	0.0261	0.0258	0.0003
4:30	4	617	0.0266	0.0264	0.0003
4:45	4	515	0.0278	0.0275	0.0003
5:00	4	428	0.0284	0.0281	0.0003
5:15	4	355	0.0296	0.0293	0.0003
5:30	5	294	0.0303	0.0300	0.0003

5:45	5	243	0.0317	0.0313	0.0003
6:00	5	201	0.0324	0.0321	0.0003
6:15	5	166	0.0339	0.0336	0.0003
6:30	5	137	0.0347	0.0344	0.0003
6:45	6	113	0.0364	0.0360	0.0004
7:00	6	94	0.0373	0.0369	0.0004
7:15	6	78	0.0392	0.0388	0.0004
7:30	6	64	0.0402	0.0398	0.0004
7:45	6	53	0.0423	0.0419	0.0004
8:00	7	44	0.0434	0.0430	0.0004
8:15	7	37	0.0444	0.0379	0.0065
8:30	7	31	0.0446	0.0247	0.0199
8:45	8	26	0.0453	0.0247	0.0205
9:00	12	21	0.0456	0.0247	0.0209
9:15	23	18	0.0465	0.0247	0.0217
9:30	43	15	0.0470	0.0247	0.0222
9:45	71	13	0.0482	0.0247	0.0234
10:00	106	11	0.0489	0.0247	0.0241
10:15	145	9	0.0506	0.0247	0.0259
10:30	185	7	0.0517	0.0247	0.0269
10:45	226	6	0.0544	0.0247	0.0296
11:00	266	5	0.0561	0.0247	0.0314
11:15	305	4	0.0606	0.0247	0.0359
11:30	342	4	0.0636	0.0247	0.0389
11:45	380	3	0.0721	0.0247	0.0473
12:00	418	3	0.0781	0.0247	0.0533
12:15	459	2	0.0844	0.0247	0.0596
12:30	504	2	0.0864	0.0247	0.0616
12:45	555	2	0.0911	0.0247	0.0664
13:00	614	1	0.0939	0.0247	0.0691
13:15	679	1	0.1004	0.0247	0.0757
13:30	751	1	0.1043	0.0247	0.0796
13:45	828	1	0.1138	0.0247	0.0890
14:00	909	1	0.1196	0.0247	0.0948
14:15	993	1	0.1254	0.0247	0.1006
14:30	1081	1	0.1303	0.0247	0.1056
14:45	1175	0	0.1861	0.0247	0.1613
15:00	1274	0	0.2124	0.0247	0.1877
15:15	1383	0	0.3194	0.0247	0.2947
15:30	1514	0	0.4627	0.0247	0.4379
15:45	1688	0	1.0762	0.0247	1.0515
16:00	1946	0	1.5391	0.0247	1.5144
16:15	2385	0	0.6575	0.0247	0.6327
16:30	3166	0	0.2528	0.0247	0.2281
16:45	4356	0	0.1491	0.0247	0.1244
17:00	5779	0	0.1233	0.0247	0.0986
17:15	7121	0	0.1087	0.0247	0.0840
17:30	8124	0	0.0970	0.0247	0.0722
17:45	8678	0	0.0886	0.0247	0.0639
18:00	8796	0	0.0825	0.0247	0.0578
18:15	8564	0	0.0674	0.0247	0.0426
18:30	8087	0	0.0582	0.0247	0.0334
18:45	7462	0	0.0529	0.0247	0.0282
19:00	6765	0	0.0497	0.0247	0.0249
19:15	6052	0	0.0475	0.0247	0.0228
19:30	5356	0	0.0460	0.0247	0.0213

19:45	4703	0	0.0449	0.0247	0.0202
20:00	4104	0	0.0441	0.0247	0.0194
20:15	3565	0	0.0412	0.0247	0.0165
20:30	3089	0	0.0382	0.0247	0.0135
20:45	2672	0	0.0355	0.0247	0.0108
21:00	2311	0	0.0331	0.0247	0.0084
21:15	1999	0	0.0310	0.0247	0.0062
21:30	1730	0	0.0290	0.0247	0.0042
21:45	1497	0	0.0272	0.0247	0.0025
22:00	1295	0	0.0256	0.0247	0.0008
22:15	1119	0	0.0241	0.0239	0.0002
22:30	964	0	0.0227	0.0225	0.0002
22:45	829	0	0.0215	0.0213	0.0002
23:00	710	0	0.0203	0.0201	0.0002
23:15	605	0	0.0193	0.0191	0.0002
23:30	514	0	0.0183	0.0181	0.0002
23:45	435	0	0.0174	0.0172	0.0002
24:00	367	0	0.0166	0.0164	0.0002
24:15	309				
24:30	259				
24:45	217				
25:00	182				
25:15	153				
25:30	128				
25:45	107				
26:00	90				
26:15	75				
26:30	63				
26:45	53				
27:00	44				
27:15	37				
27:30	31				
27:45	26				
28:00	22				
28:15	19				
28:30	16				
28:45	13				
29:00	11				
29:15	10				
29:30	8				
29:45	7				
30:00	6				
30:15	5				
30:30	4				
30:45	4				
31:00	3				
31:15	3				
31:30	2				
31:45	2				
32:00	2				
32:15	1				
32:30	1				
32:45	1				
33:00	1				
33:15	1				
33:30	1				

33:45	1				
34:00	1				
34:15	0				
TOTALS:	2977.7 (ac-ft)	1.000 (inch)	8.964 (inches)	2.419 (inches)	6.545 (inches)

The rainfall which would produce the Standard Project Flood (SPF) was developed as outlined in EM 1110-2-1411 and distributed in time according to Southwestern Division recommendations. The 24-hour index rainfall of 14.15 inches (200 square miles) was adjusted for duration and drainage area. The maximum half-hour and quarter-hour rainfalls were obtained by multiplying the maximum 6-hour rainfall value by 0.33 and 0.22, respectively. A storm transposition coefficient of 1.0 was used in accordance with Section 2-03B of EM 1110-2-1411. Table A-12 presents a sample of the SPF rainfall distribution for the same subbasin.

TABLE A-12

SPF RAINFALL DISTRIBUTION

BROWNWOOD - G.I. RECON - AUGUST 1993
SPF EVENT STORM CENTERING ON
SUBAREA 1 - WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#3
MASS RAINFALL AND AREA REDUCTION FACTORS
DRAINAGE AREA = 8.53 SQUARE MILES

DURATION (hours)	**POINT RAINFALL** (inches)	**REDUCTION FACTOR**	**EFFECTIVE RAINFALL** (inches)
0.25	11.1712	0.2200	2.4577
0.5	11.1712	0.3300	3.6865
1	11.1712	0.5000	5.5856
2	11.1712	0.6900	7.7082
3	11.1712	0.8000	8.9370
6	16.7674	0.6663	11.1712
12	16.7674	0.8278	13.8792
24	14.1500	1.1850	16.7674
48	14.1500	1.3232	18.7236
72	14.1500	1.3951	19.7408
96	14.1500	1.4132	19.9971

			RAINFALL CURVES		
TIME	**FLOOD HYDROGRAPH** (cfs)	**UNIT HYDROGRAPH** (cfs)	**RAIN** (inches)	**LOSS** (inches)	**EXCESS** (inches)
0:15	0	0	0.0011	0.0011	0.0000
0:30	0	10	0.0011	0.0011	0.0000
0:45	0	113	0.0011	0.0011	0.0000
1:00	0	408	0.0012	0.0011	0.0000
1:15	0	846	0.0012	0.0012	0.0000
1:30	0	1291	0.0012	0.0012	0.0000
1:45	0	1634	0.0012	0.0012	0.0000
2:00	0	1834	0.0012	0.0012	0.0000
2:15	0	1894	0.0013	0.0013	0.0000

2:30	0	1846	0.0013	0.0013	0.0000
2:45	0	1724	0.0013	0.0013	0.0000
3:00	0	1561	0.0014	0.0013	0.0000
3:15	0	1382	0.0014	0.0014	0.0000
3:30	0	1201	0.0014	0.0014	0.0000
3:45	0	1030	0.0015	0.0014	0.0000
4:00	0	875	0.0015	0.0015	0.0000
4:15	0	737	0.0015	0.0015	0.0000
4:30	0	617	0.0015	0.0015	0.0000
4:45	0	515	0.0016	0.0016	0.0000
5:00	0	428	0.0016	0.0016	0.0000
5:15	0	355	0.0017	0.0016	0.0000
5:30	0	294	0.0017	0.0017	0.0000
5:45	0	243	0.0017	0.0017	0.0000
6:00	0	201	0.0018	0.0018	0.0000
6:15	0	166	0.0018	0.0018	0.0000
6:30	0	137	0.0019	0.0018	0.0000
6:45	0	113	0.0019	0.0019	0.0000
7:00	0	94	0.0020	0.0019	0.0000
7:15	0	78	0.0020	0.0020	0.0000
7:30	0	64	0.0021	0.0020	0.0000
7:45	0	53	0.0021	0.0021	0.0000
8:00	0	44	0.0022	0.0021	0.0000
8:15	0	37	0.0022	0.0022	0.0000
8:30	0	31	0.0023	0.0023	0.0000
8:45	0	26	0.0024	0.0023	0.0000
9:00	0	21	0.0024	0.0024	0.0000
9:15	0	18	0.0025	0.0025	0.0000
9:30	0	15	0.0026	0.0025	0.0000
9:45	0	13	0.0027	0.0026	0.0000
10:00	0	11	0.0027	0.0027	0.0000
10:15	0	9	0.0028	0.0028	0.0000
10:30	0	7	0.0029	0.0028	0.0000
10:45	0	6	0.0030	0.0030	0.0000
11:00	0	5	0.0031	0.0030	0.0000
11:15	1	4	0.0032	0.0032	0.0000
11:30	1	4	0.0033	0.0032	0.0000
11:45	1	3	0.0034	0.0034	0.0000
12:00	1	3	0.0035	0.0035	0.0000
12:15	1	2	0.0037	0.0036	0.0000
12:30	1	2	0.0037	0.0037	0.0000
12:45	1	2	0.0039	0.0039	0.0000
13:00	1	1	0.0040	0.0040	0.0000
13:15	1	1	0.0042	0.0042	0.0000
13:30	1	1	0.0043	0.0043	0.0000
13:45	1	1	0.0045	0.0045	0.0000
14:00	1	1	0.0047	0.0046	0.0000
14:15	1	1	0.0049	0.0049	0.0000
14:30	1	1	0.0050	0.0050	0.0001
14:45	1	0	0.0053	0.0053	0.0001
15:00	1	0	0.0055	0.0054	0.0001
15:15	1	0	0.0058	0.0057	0.0001
15:30	1	0	0.0060	0.0059	0.0001
15:45	1	0	0.0063	0.0063	0.0001
16:00	1	0	0.0065	0.0065	0.0001
16:15	1	0	0.0067	0.0067	0.0001

16:30	1	0	0.0068	0.0067	0.0001
16:45	1	0	0.0069	0.0069	0.0001
17:00	1	0	0.0070	0.0069	0.0001
17:15	1	0	0.0071	0.0071	0.0001
17:30	1	0	0.0072	0.0071	0.0001
17:45	1	0	0.0074	0.0073	0.0001
18:00	1	0	0.0074	0.0074	0.0001
18:15	1	0	0.0076	0.0075	0.0001
18:30	1	0	0.0076	0.0076	0.0001
18:45	1	0	0.0078	0.0077	0.0001
19:00	1	0	0.0079	0.0078	0.0001
19:15	1	0	0.0080	0.0079	0.0001
19:30	1	0	0.0081	0.0080	0.0001
19:45	2	0	0.0082	0.0082	0.0001
20:00	2	0	0.0083	0.0082	0.0001
20:15	2	0	0.0085	0.0084	0.0001
20:30	2	0	0.0086	0.0085	0.0001
20:45	2	0	0.0087	0.0086	0.0001
21:00	2	0	0.0088	0.0087	0.0001
21:15	2	0	0.0090	0.0089	0.0001
21:30	2	0	0.0090	0.0089	0.0001
21:45	2	0	0.0092	0.0091	0.0001
22:00	2	0	0.0093	0.0092	0.0001
22:15	2	0	0.0095	0.0094	0.0001
22:30	2	0	0.0095	0.0094	0.0001
22:45	2	0	0.0097	0.0096	0.0001
23:00	2	0	0.0098	0.0097	0.0001
23:15	2	0	0.0100	0.0099	0.0001
23:30	2	0	0.0101	0.0100	0.0001
23:45	2	0	0.0102	0.0101	0.0001
24:00	2	0	0.0103	0.0102	0.0001
24:15	2	0	0.0105	0.0104	0.0001
24:30	2	0	0.0106	0.0105	0.0001
24:45	2	0	0.0108	0.0107	0.0001
25:00	2	0	0.0109	0.0108	0.0001
25:15	2	0	0.0111	0.0110	0.0001
25:30	2	0	0.0112	0.0110	0.0001
25:45	2	0	0.0114	0.0112	0.0001
26:00	2	0	0.0114	0.0113	0.0001
26:15	2	0	0.0116	0.0115	0.0001
26:30	2	0	0.0117	0.0116	0.0001
26:45	2	0	0.0119	0.0118	0.0001
27:00	2	0	0.0120	0.0119	0.0001
27:15	2	0	0.0122	0.0121	0.0001
27:30	2	0	0.0123	0.0122	0.0001
27:45	2	0	0.0126	0.0124	0.0001
28:00	2	0	0.0127	0.0125	0.0001
28:15	2	0	0.0129	0.0127	0.0001
28:30	2	0	0.0130	0.0129	0.0001
28:45	3	0	0.0132	0.0131	0.0001
29:00	3	0	0.0133	0.0132	0.0001
29:15	3	0	0.0135	0.0134	0.0001
29:30	3	0	0.0136	0.0135	0.0001
29:45	3	0	0.0139	0.0137	0.0001
30:00	3	0	0.0140	0.0138	0.0001
30:15	3	0	0.0142	0.0141	0.0001

30:30	3	0	0.0143	0.0142	0.0001
30:45	3	0	0.0146	0.0144	0.0001
31:00	3	0	0.0147	0.0145	0.0001
31:15	3	0	0.0149	0.0148	0.0001
31:30	3	0	0.0150	0.0149	0.0002
31:45	3	0	0.0153	0.0151	0.0002
32:00	3	0	0.0154	0.0153	0.0002
32:15	3	0	0.0155	0.0153	0.0002
32:30	3	0	0.0155	0.0154	0.0002
32:45	3	0	0.0156	0.0154	0.0002
33:00	3	0	0.0156	0.0154	0.0002
33:15	3	0	0.0156	0.0155	0.0002
33:30	3	0	0.0157	0.0155	0.0002
33:45	3	0	0.0157	0.0155	0.0002
34:00	3	0	0.0157	0.0156	0.0002
34:15	3	0	0.0158	0.0156	0.0002
34:30	3	0	0.0158	0.0157	0.0002
34:45	3	0	0.0159	0.0157	0.0002
35:00	3	0	0.0159	0.0157	0.0002
35:15	3	0	0.0160	0.0158	0.0002
35:30	3	0	0.0160	0.0158	0.0002
35:45	3	0	0.0161	0.0159	0.0002
36:00	3	0	0.0161	0.0159	0.0002
36:15	3	0	0.0162	0.0160	0.0002
36:30	3	0	0.0162	0.0161	0.0002
36:45	3	0	0.0163	0.0161	0.0002
37:00	3	0	0.0164	0.0162	0.0002
37:15	3	0	0.0164	0.0163	0.0002
37:30	3	0	0.0165	0.0163	0.0002
37:45	3	0	0.0166	0.0164	0.0002
38:00	4	0	0.0167	0.0165	0.0002
38:15	4	0	0.0168	0.0166	0.0002
38:30	4	0	0.0168	0.0167	0.0002
38:45	4	0	0.0170	0.0168	0.0002
39:00	4	0	0.0170	0.0169	0.0002
39:15	4	0	0.0172	0.0170	0.0002
39:30	4	0	0.0173	0.0171	0.0002
39:45	4	0	0.0174	0.0172	0.0002
40:00	4	0	0.0175	0.0173	0.0002
40:15	4	0	0.0177	0.0175	0.0002
40:30	4	0	0.0178	0.0176	0.0002
40:45	4	0	0.0180	0.0178	0.0002
41:00	4	0	0.0181	0.0179	0.0002
41:15	4	0	0.0184	0.0182	0.0002
41:30	4	0	0.0185	0.0183	0.0002
41:45	4	0	0.0188	0.0186	0.0002
42:00	4	0	0.0189	0.0188	0.0002
42:15	4	0	0.0193	0.0191	0.0002
42:30	4	0	0.0194	0.0193	0.0002
42:45	4	0	0.0198	0.0196	0.0002
43:00	4	0	0.0200	0.0198	0.0002
43:15	4	0	0.0205	0.0198	0.0007
43:30	4	0	0.0208	0.0198	0.0010
43:45	4	0	0.0213	0.0198	0.0015
44:00	4	0	0.0216	0.0198	0.0018
44:15	5	0	0.0223	0.0198	0.0025

44:30	6	0	0.0226	0.0198	0.0028
44:45	8	0	0.0235	0.0198	0.0037
45:00	11	0	0.0239	0.0198	0.0041
45:15	14	0	0.0249	0.0198	0.0051
45:30	19	0	0.0255	0.0198	0.0057
45:45	24	0	0.0268	0.0198	0.0070
46:00	31	0	0.0275	0.0198	0.0077
46:15	39	0	0.0292	0.0198	0.0094
46:30	47	0	0.0301	0.0198	0.0103
46:45	58	0	0.0323	0.0198	0.0125
47:00	69	0	0.0336	0.0198	0.0138
47:15	83	0	0.0366	0.0198	0.0168
47:30	98	0	0.0383	0.0198	0.0185
47:45	115	0	0.0425	0.0198	0.0227
48:00	135	0	0.0451	0.0198	0.0253
48:15	157	0	0.0468	0.0198	0.0270
48:30	184	0	0.0471	0.0198	0.0273
48:45	213	0	0.0476	0.0198	0.0278
49:00	246	0	0.0479	0.0198	0.0281
49:15	282	0	0.0485	0.0198	0.0287
49:30	318	0	0.0488	0.0198	0.0290
49:45	355	0	0.0495	0.0198	0.0297
50:00	389	0	0.0498	0.0198	0.0300
50:15	422	0	0.0506	0.0198	0.0308
50:30	453	0	0.0510	0.0198	0.0312
50:45	481	0	0.0519	0.0198	0.0321
51:00	506	0	0.0524	0.0198	0.0326
51:15	530	0	0.0534	0.0198	0.0336
51:30	552	0	0.0539	0.0198	0.0341
51:45	572	0	0.0551	0.0198	0.0353
52:00	592	0	0.0558	0.0198	0.0360
52:15	610	0	0.0571	0.0198	0.0373
52:30	628	0	0.0579	0.0198	0.0381
52:45	646	0	0.0595	0.0198	0.0397
53:00	664	0	0.0604	0.0198	0.0406
53:15	682	0	0.0623	0.0198	0.0425
53:30	700	0	0.0633	0.0198	0.0435
53:45	719	0	0.0656	0.0198	0.0458
54:00	739	0	0.0669	0.0198	0.0471
54:15	760	0	0.0697	0.0198	0.0499
54:30	782	0	0.0713	0.0198	0.0515
54:45	806	0	0.0747	0.0198	0.0549
55:00	832	0	0.0767	0.0198	0.0569
55:15	860	0	0.0810	0.0198	0.0612
55:30	890	0	0.0834	0.0198	0.0636
55:45	923	0	0.0889	0.0198	0.0691
56:00	958	0	0.0921	0.0198	0.0723
56:15	998	0	0.0948	0.0198	0.0750
56:30	1041	0	0.0956	0.0198	0.0758
56:45	1089	0	0.0974	0.0198	0.0776
57:00	1141	0	0.0984	0.0198	0.0786
57:15	1195	0	0.1006	0.0198	0.0808
57:30	1250	0	0.1019	0.0198	0.0821
57:45	1306	0	0.1049	0.0198	0.0851
58:00	1360	0	0.1066	0.0198	0.0868
58:15	1413	0	0.1105	0.0198	0.0907

58:30	1464	0	0.1128	0.0198	0.0930
58:45	1514	0	0.1183	0.0198	0.0985
59:00	1564	0	0.1215	0.0198	0.1017
59:15	1614	0	0.1293	0.0198	0.1095
59:30	1666	0	0.1341	0.0198	0.1143
59:45	1720	0	0.1459	0.0198	0.1261
60:00	1779	0	0.1533	0.0198	0.1335
60:15	1843	0	0.1604	0.0198	0.1406
60:30	1916	0	0.1629	0.0198	0.1431
60:45	1998	0	0.1694	0.0198	0.1496
61:00	2089	0	0.1738	0.0198	0.1540
61:15	2190	0	0.1865	0.0198	0.1667
61:30	2297	0	0.1957	0.0198	0.1759
61:45	2409	0	0.2249	0.0198	0.2051
62:00	2527	0	0.2492	0.0198	0.2294
62:15	2654	0	0.2897	0.0198	0.2699
62:30	2795	0	0.3148	0.0198	0.2950
62:45	2962	0	0.4120	0.0198	0.3922
63:00	3164	0	0.4860	0.0198	0.4662
63:15	3415	0	0.6572	0.0198	0.6374
63:30	3737	0	0.8551	0.0198	0.8353
63:45	4164	0	1.2288	0.0198	1.2090
64:00	4746	0	2.4577	0.0198	2.4379
64:15	5570	0	1.0440	0.0198	1.0242
64:30	6807	0	0.5674	0.0198	0.5476
64:45	8562	0	0.3523	0.0198	0.3325
65:00	10627	0	0.2720	0.0198	0.2522
65:15	12590	0	0.2080	0.0198	0.1882
65:30	14093	0	0.1794	0.0198	0.1596
65:45	14957	0	0.1658	0.0198	0.1460
66:00	15173	0	0.1583	0.0198	0.1385
66:15	14846	0	0.1396	0.0198	0.1198
66:30	14121	0	0.1252	0.0198	0.1054
66:45	13145	0	0.1154	0.0198	0.0956
67:00	12042	0	0.1084	0.0198	0.0886
67:15	10901	0	0.1033	0.0198	0.0835
67:30	9784	0	0.0995	0.0198	0.0797
67:45	8728	0	0.0965	0.0198	0.0767
68:00	7757	0	0.0941	0.0198	0.0743
68:15	6881	0	0.0861	0.0198	0.0663
68:30	6102	0	0.0787	0.0198	0.0589
68:45	5417	0	0.0729	0.0198	0.0531
69:00	4818	0	0.0683	0.0198	0.0485
69:15	4295	0	0.0645	0.0198	0.0447
69:30	3837	0	0.0613	0.0198	0.0415
69:45	3436	0	0.0587	0.0198	0.0389
70:00	3083	0	0.0564	0.0198	0.0366
70:15	2772	0	0.0545	0.0198	0.0347
70:30	2497	0	0.0529	0.0198	0.0331
70:45	2254	0	0.0515	0.0198	0.0317
71:00	2039	0	0.0502	0.0198	0.0304
71:15	1850	0	0.0491	0.0198	0.0293
71:30	1683	0	0.0482	0.0198	0.0284
71:45	1536	0	0.0473	0.0198	0.0275
72:00	1406	0	0.0466	0.0198	0.0268
72:15	1293	0	0.0403	0.0198	0.0205

72:30	1193	0	0.0350	0.0198	0.0152
72:45	1105	0	0.0311	0.0198	0.0113
73:00	1025	0	0.0283	0.0198	0.0085
73:15	950	0	0.0261	0.0198	0.0063
73:30	878	0	0.0244	0.0198	0.0046
73:45	807	0	0.0230	0.0198	0.0032
74:00	736	0	0.0219	0.0198	0.0021
74:15	666	0	0.0210	0.0198	0.0012
74:30	597	0	0.0203	0.0198	0.0005
74:45	531	0	0.0196	0.0194	0.0002
75:00	468	0	0.0191	0.0189	0.0002
75:15	409	0	0.0186	0.0185	0.0002
75:30	355	0	0.0182	0.0181	0.0002
75:45	306	0	0.0179	0.0177	0.0002
76:00	261	0	0.0176	0.0174	0.0002
76:15	222	0	0.0173	0.0172	0.0002
76:30	188	0	0.0171	0.0169	0.0002
76:45	159	0	0.0169	0.0167	0.0002
77:00	134	0	0.0167	0.0165	0.0002
77:15	113	0	0.0165	0.0164	0.0002
77:30	95	0	0.0164	0.0162	0.0002
77:45	80	0	0.0163	0.0161	0.0002
78:00	67	0	0.0161	0.0160	0.0002
78:15	57	0	0.0160	0.0159	0.0002
78:30	48	0	0.0159	0.0158	0.0002
78:45	41	0	0.0158	0.0157	0.0002
79:00	34	0	0.0158	0.0156	0.0002
79:15	29	0	0.0157	0.0155	0.0002
79:30	25	0	0.0156	0.0155	0.0002
79:45	22	0	0.0155	0.0154	0.0002
80:00	19	0	0.0155	0.0153	0.0002
80:15	16	0	0.0152	0.0150	0.0002
80:30	14	0	0.0148	0.0147	0.0001
80:45	13	0	0.0144	0.0143	0.0001
81:00	11	0	0.0141	0.0140	0.0001
81:15	10	0	0.0138	0.0136	0.0001
81:30	9	0	0.0134	0.0133	0.0001
81:45	8	0	0.0131	0.0130	0.0001
82:00	7	0	0.0128	0.0126	0.0001
82:15	7	0	0.0125	0.0123	0.0001
82:30	6	0	0.0121	0.0120	0.0001
82:45	6	0	0.0118	0.0117	0.0001
83:00	5	0	0.0115	0.0114	0.0001
83:15	5	0	0.0113	0.0111	0.0001
83:30	5	0	0.0110	0.0109	0.0001
83:45	4	0	0.0107	0.0106	0.0001
84:00	4	0	0.0104	0.0103	0.0001
84:15	4	0	0.0101	0.0100	0.0001
84:30	4	0	0.0099	0.0098	0.0001
84:45	4	0	0.0096	0.0095	0.0001
85:00	3	0	0.0094	0.0093	0.0001
85:15	3	0	0.0091	0.0090	0.0001
85:30	3	0	0.0089	0.0088	0.0001
85:45	3	0	0.0086	0.0086	0.0001
86:00	3	0	0.0084	0.0083	0.0001
86:15	3	0	0.0082	0.0081	0.0001

storm reproductions, it was determined that the losses calculated in 1957 more closely matched those for the watersheds that were predominantly clay; therefore, they became the clay losses. A companion set of sand losses were then developed by increasing the clay losses, using losses determined from storm reproductions in the sandy watersheds as a guide. Subsequent studies, including flow frequency analyses have been used to verify the reasonableness of the Dallas-Fort Worth area clay and sand losses.

TABLE A-13

RAINFALL LOSSES

	ANNUAL EXCEEDANCE PROBABILITY	EFFECTIVE RECURRENCE INTERVAL (years)	INITIAL ABSTRACTION (inches)	INFILTRATION RATE (iph)
CLAYEY SOILS:				
		1	1.50	0.20
	0.500	2	1.50	0.20
	0.200	5	1.30	0.16
	0.100	10	1.12	0.14
	0.040	25	0.95	0.12
	0.020	50	0.84	0.10
	0.010	100	0.75	0.07
	0.002	500	0.50	0.05
	SPF EVENT		0.50	0.05
SANDY SOILS:				
		1	2.10	0.26
	0.500	2	2.10	0.26
	0.200	5	1.80	0.21
	0.100	10	1.50	0.18
	0.040	25	1.30	0.15
	0.020	50	1.10	0.13
	0.010	100	0.90	0.10
	0.002	500	0.60	0.08
	SPF EVENT		0.60	0.08

After the runoff was computed, Snyder's unit hydrographs were developed for each subbasin in the study area watersheds. The unit hydrograph Tp value for each subbasin was derived using methodology described in the reports:

"Synthetic Hydrograph Relationships, Trinity River Tributaries,
Fort Worth-Dallas Urban Area", T.L. Nelson, dated 1970.

"Effects of Urbanization on Various Frequency Peak Discharges",
Paul K. Rodman, dated October 1977.

Each of these reports discusses the development of the Blackland Prairie Clay and/or the Cross Timber Sandy Loam Urbanization Curves for the Dallas-Fort Worth area. These curves relate Tp to certain measurable subbasin parameters for a specific percent urbanization and

86:30	3	0	0.0079	0.0079	0.0001
86:45	3	0	0.0077	0.0076	0.0001
87:00	2	0	0.0075	0.0074	0.0001
87:15	2	0	0.0073	0.0072	0.0001
87:30	2	0	0.0071	0.0070	0.0001
87:45	2	0	0.0069	0.0068	0.0001
88:00	2	0	0.0067	0.0066	0.0001
88:15	2	0	0.0061	0.0061	0.0001
88:30	2	0	0.0056	0.0056	0.0001
88:45	2	0	0.0052	0.0051	0.0001
89:00	2	0	0.0048	0.0047	0.0000
89:15	2	0	0.0044	0.0044	0.0000
89:30	2	0	0.0041	0.0041	0.0000
89:45	2	0	0.0038	0.0038	0.0000
90:00	2	0	0.0036	0.0035	0.0000
90:15	2	0	0.0033	0.0033	0.0000
90:30	1	0	0.0031	0.0031	0.0000
90:45	1	0	0.0029	0.0029	0.0000
91:00	1	0	0.0028	0.0027	0.0000
91:15	1	0	0.0026	0.0026	0.0000
91:30	1	0	0.0025	0.0024	0.0000
91:45	1	0	0.0023	0.0023	0.0000
92:00	1	0	0.0022	0.0022	0.0000
92:15	1	0	0.0021	0.0021	0.0000
92:30	1	0	0.0020	0.0020	0.0000
92:45	1	0	0.0019	0.0019	0.0000
93:00	1	0	0.0018	0.0018	0.0000
93:15	1	0	0.0017	0.0017	0.0000
93:30	1	0	0.0016	0.0016	0.0000
93:45	1	0	0.0016	0.0015	0.0000
94:00	1	0	0.0015	0.0015	0.0000
94:15	1	0	0.0014	0.0014	0.0000
94:30	1	0	0.0014	0.0014	0.0000
94:45	1	0	0.0013	0.0013	0.0000
95:00	1	0	0.0013	0.0013	0.0000
95:15	0	0	0.0012	0.0012	0.0000
TOTALS:	6886.19	1	19.997	4.860	15.137
	(ac-ft)	(inch)	(inches)	(inches)	(inches)

Runoff volumes were computed by subtracting the applicable losses from the incremental rainfall amounts. Losses were deducted using the "block and uniform" loss method. The initial abstractions and hourly loss rates developed for the Dallas-Fort Worth vicinity were adopted for the Pecan Bayou watershed. These losses, presented in Table A-13, are based on an analysis originally done in 1957. In this analysis, the initial abstractions and hourly loss rates were determined for 10 storm reproductions on the East Fork of the Trinity River near Rockwall, Texas. Losses from these storm reproductions ranged from maximums of a 1.30-inch initial abstraction and a 0.16-iph uniform loss rate, to minimums of a 0.50-inch initial abstraction and a 0.05-iph uniform loss rate. Based on these storm reproductions, the 2-year frequency storm was assigned an initial abstraction and hourly loss of 1.50 inches and 0.20 iph, respectively. The 1000-year frequency storm was assigned an initial abstraction and hourly loss of 0.50 inches and 0.05 iph, respectively. The loss rates for the 5-year through 100-year frequency storms were then interpolated. Later studies adopted the 1-year losses to be the same as that of the 2-year event and the losses for the 500-year and SPF events to be the same as that of the 1000-year event. An additional 30 storm reproductions were used in the development of the Blackland Prairie Clay and Cross Timber Sandy Loam Urbanization Curves in 1970 and 1977. In the analysis of these percent sand. Each set of curves were based on flood hydrograph reproductions of predominantly clayey or sandy watersheds in the Dallas-Fort Worth area. The pertinent data for these flood hydrograph reproductions for clayey and sandy watersheds are presented in Tables A-14 and A-15, respectively. The urbanization curves, as displayed on Plates A-6 and A-7, have been successfully applied to a number of flood insurance and planning studies in the region with satisfactory results. They relate Tp to the quantity:

$$(L)(LCA)/(SST)^{0.5}$$

where: Tp = the lag time in hours from the midpoint of the unit rainfall duration to the peak of the unit hydrograph
L = the stream mileage from the discharge point to the upstream limits of the drainage area
LCA = the stream mileage from the discharge point to the geographical centroid of the drainage area
SST = the weighted stream slope over the stream length, from 10 percent of L to 85 percent of L, above the discharge point, in feet per mile.

Based on the percentages of clay and sand, the Tp value was computed for each subbasin by interpolating between the Blackland Prairie Clay and Cross Timber Sandy Loam Urbanization Curves. The generalized Snyder's unit hydrograph peaking coefficient (640CP) value of 460, which was obtained from data developed during the generation of the urbanization curves, was used for this study area. The unit hydrograph data for each subbasin is presented in Table A-16. Physically measurable subbasin parameters were taken from the 56 standard 1:24,000 scale USGS topographic quadrangle maps covering the overall watershed. The 16 larger subbasins (of 165 total) are located upstream from the Lake Brownwood dam.

Once rainfall excesses for each frequency event and unit hydrographs were developed, multiple flood hydrographs were generated for each subbasin. These hydrographs were routed using the Modified Puls technique. Discharge versus storage relationships for Pecan Bayou (up to Lake Brownwood) and both Willis and South Willis Creeks were determined using HEC-2 backwater models which were developed concurrently by the Hydraulic Design Section, FWD, USACE.

TABLE A-14

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED TO DEVELOP THE BLACKLAND PRAIRIE CLAY URBANIZATION CURVES FOR THE DALLAS-FORT WORTH AREA

Gage Location	Drainage Area (sq.mi.)	Average Rainfall (inches)	Direct Runoff (inches)	Observed Peak (cfs)	640 CP	TP (hours)	Date	0.5 LLca/S	Percent Urban
White Rock Creek at Keller Springs Road	29.4	3.39	1.49	8300	590	2.77	6 May 69	27.6	4
		1.97	0.84	4420	612	3.50	29-30 Jun 62	27.6	0
		5.84	2.50	9410	686	3.50	27 Jul 62	27.6	0
		1.77	0.77	3460	423	2.50	27 Sep 64	27.6	0
		2.35	0.90	3170	605	3.50	18 Nov 64	27.6	0
		1.75	0.65	4560	868	3.50	27-28 May 64	27.6	0
		2.52	1.43	9020	763	3.50	28 Apr 66	27.6	0
				Averages:	650	3.25			1
White Rock Creek at Greenville Avenue	66.4	3.93	1.65	24500	620	2.50	8 Oct 62	78.4	10
		1.56	0.70	6940	759	4.50	27 Sep 64	78.4	10

		1.96	1.00	7500	626	4.50	18 Nov 64	78.4	10
		3.37	2.44	11000	616	5.50	8-9 Feb 65	78.4	10
		2.64	1.77	13800	469	3.50	10-11 May 65	78.4	10
				Averages:	618	4.10			10
Turtle Creek at Dallas, Texas	7.98	1.73	0.64	3050	439	0.75	30 Apr 62	2.9	100
		4.36	2.18	4640	338	0.75	27 Jul 62	2.9	100
		3.80	1.68	3450	291	0.75	8 Oct 62	2.9	100
		2.82	1.81	4290	479	0.75	28 Apr 63	2.9	100
		2.12	1.66	4520	489	0.75	19 May 65	2.9	100
		3.55	3.04	12200	658	0.75	28 Apr 66	2.9	100
				Averages:	449	0.75			100
Bachman Branch at Midway Road	10.0	5.35	3.21	9200	255	0.75	8 Oct 62	2.6	
		4.10	1.28	3620	468	1.25	20-21 Sep 64	2.6	
		1.10	0.69	2910	337	0.75	21 Sep 64	2.6	
		1.36	0.58	3050	195	0.25	22 Sep 64	2.6	
		2.36	1.52	5170	595	1.25	10 May 65	2.6	
				Averages:	370	0.85		2.6	70
Joes Creek at State Highway 114	7.51	4.77	3.71	6350	316	1.25	28 Apr 66	2.9	55
		4.64	3.28	7300	380	0.58	8 Oct 62	2.9	50
				Averages:	348	0.92		2.9	53
Duck Creek at Garland, Texas (Beltline Road)	31.6	4.38	3.52	10500	550	3.83	6 May 69	23.5	37
		3.56	1.99	7400	388	2.50	26 Apr 58	23.5	37
		0.77	0.64	2140	364	3.50	28-29 Apr 58	23.5	
		3.05	1.09	4160	358	2.50	1 Oct 59	23.5	
		7.00	4.54	16000	395	2.50	27 Jul 62	23.5	
		3.02	1.63	7400	530	2.50	28 Apr 63	23.5	
		3.53	1.78	5620	497	3.50	9 Feb 65	23.5	
		3.91	2.72	9500	325	2.50	28 Apr 66	23.5	
		2.46	1.81	8600	395	2.50	29 Apr 66	23.5	
				Averages:	422	2.87		23.5	35
Big Fossil Creek at Haltom City	53.8	6.15	3.73	27200	590	3.63	7 Sep 62	47.6	5
		4.43	2.69	7770	420	4.50	25-26 Apr 57	47.6	5
		5.86	4.62	13000	420	4.50	25-26 May 57	47.6	5
		6.54	2.06	18300	603	3.50	24-25 Jun 61	47.6	5
		5.29	1.69	12600	462	3.50	30 Sep-1 Oct 59	47.6	5
				Averages:	499	3.93		47.6	5
Village Creek at Handley, Texas	130.0	1.54	0.50	4180	460	5.20	19 May 26	95.6	
		3.41	0.85	9400	460	5.20	1 Oct 27	95.6	
		3.46	1.38	14800	460	5.20	17 Dec 28	95.6	
				Averages:	460	5.20		95.6	0
Duck Creek at Buckingham Road	7.90	2.50	0.90	2500	250	0.64	30 May 70	5.32	40
		3.17	1.79	3960	280	0.89	16 Sep 74	5.32	60
				Averages:	265	0.77		5.32	50
South Mesquite Creek at Highway 352	13.4	2.89	1.86	3420	400	1.89	23 Apr 73	6.61	65
		2.30	1.58	3090	420	1.75	20 Sep 73	6.61	65
				Averages:	410	1.82		6.61	65
Marine Creek at NW 33rd Street	17.3	1.45	0.56	1680	405	2.25	26 Apr 57	6.30	5
Sycamore Creek at I.H. 35W	17.7	1.38	0.28	1140	450	1.77	30 May 70	7.19	18
Rowlett Creek near Sachse (Highway 78)	120.3	3.40	2.01	24400	600	8.36	6 May 69	112.70	4
		3.41	2.48	24700	600	6.62	9 Dec 71	112.70	6
				Averages:	600	7.49			5
Five Mile Creek at Lancaster, Texas	37.9	1.85	0.70	7040	460	1.55	30 May 70	8.44	55
		2.36	0.85	8540	440	1.55	7 Jul 73	8.44	55
				Averages:	450	1.55			55
Five Mile Creek	13.2	3.02	1.45	6180	300	0.49	30 May 70	5.91	55

at Highway 77									
Ten Mile Creek at Highway 342	52.8	3.74	1.86	8820	320	2.91	3 Jun 73	24.77	25
Cedar Creek at Bonnie View Road	9.42	2.15	0.75	4840	350	0.45	29 May 73	2.42	100
Coombs Creek at Sylvan Avenue	4.75	4.40	2.73	2960	320	0.82	6 May 69	1.64	100
Little Fossil Creek at Mesquite Street	12.3	2.12	1.28	1530	260	2.27	6 May 69	7.90	18
		1.61	0.83	1370	280	1.91	30 Apr-1 May 70	7.90	18
				Averages:	270	2.09		7.90	18
Mountain Creek near Cedar Hill	103.5	3.38	2.35	18500	433	5.60	25-26 Apr 70	86	1
		5.92	4.81	28300	324	4.95	6-8 May 69	86	1
				Averages:	379	5.28		86	1
Honey Creek SCS Site No. 12 near McKinney	1.26	1.46	1.46	1170	360	0.40	29 Apr 58	0.216	2
		1.62	1.62	1480	380	0.26	1 May 58	0.216	2
		1.03	0.95	850	550	0.73	28 Apr 66	0.216	2
		1.72	1.72	1400	550	0.62	30 Apr 66	0.216	2
				Averages:	460	0.50		0.216	2
Honey Creek SCS Site No. 11 near McKinney	2.14	1.22	0.93	1250	340	0.50	28 Apr 66	0.177	2
		2.36	2.30	3230	320	0.33	30 Apr 66	0.177	2
				Averages:	330	0.42		0.177	2

TABLE A-15

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED TO DEVELOP THE CROSS TIMBER SANDY LOAM URBANIZATION CURVES FOR THE DALLAS-FORT WORTH AREA

Gage Location	Drainage Area (sq.mi.)	Average Rainfall (inches)	Direct Runoff (inches)	Initial Abstraction (inches)	Infiltration Rate (iph)	640 CP	TP (hours)	CT	Observed Peak (cfs)	Computed Peak (cfs)	Percent Urban	Length (miles)	Centroidal Length (miles)	Weighted Slope (feet/mile)	0.5 LLca/S	Date	Remarks
Walnut Creek	62.8	3.22	1.45	0.7	0.13	450	7.87	1.7	4730	4800	1	19.72	8.38	12.6	46.5	8-10 Feb 65	90% sandy &
near Mansfield		2.08	1.22	0.5	0.07	550	7.87	1.7	5390	5200	1	19.72	8.38	12.6	46.5	30 Apr-1 May 66	10% clayey
		4.70	1.67	1.4	0.20	550	7.87	1.7	6840	6840	1	19.72	8.38	12.6	46.5	6-7 May 69	
Rush Creek at Arkansas Lane	27.11	2.89	1.20	0.6	0.18	460	5.0	1.43	2500	2510	5	11.54	5.62	14.3	17.2	12-13 Oct 73	Personal stage observations
Big Sandy Creek	333	5.00	3.15	1.75	0.01	640	13.4		53000		1				564	10-12 Jun 41	60% sandy &
Near Bridgeport	333	4.40	1.98	1.20	0.08	610	21.0		17350		1				564	7-10 Apr 42	40% clayey
					Averages:	625	17.0										
Big Sandy Creek near Bridgeport (Area modified by Lake Amon Carter)	233.2	8.72	2.86	4.60	0.06	400	11.3		19110		1				202	3-6 Oct 59	80% sandy & 20% clayey

TABLE A-16

UNIT HYDROGRAPH DATA

SUBBASIN NUMBER	DRAINAGE AREA (sq.miles)	LENGTH (miles)	CENTROIDAL LENGTH (miles)	WEIGHTED SLOPE (feet/mile)	CT	TP (hours)	TPR (hours)	QPR (cfs/sq.mi.)	QPR1 (cfs)	PERCENT URBAN	PERCENT IMPERVIOUS
1001	37.33	9.20	2.82	15.90	1.40	3.71	3.60	127.62	4764.21	0	2.7
1002	72.38	24.19	13.20	11.90	1.82	10.27	9.86	46.64	3376.02	0	0.2
1003	79.44	21.36	12.42	20.60	1.61	8.61	8.28	55.56	4413.88	0	0.2
1004	119.85	24.38	11.09	15.00	1.72	9.21	8.86	51.93	6224.02	0	0.0
1005	107.34	29.25	12.31	11.50	1.85	10.82	10.39	44.27	4751.66	0	0.3
1006	126.87	38.82	15.64	12.20	1.91	13.07	12.54	36.68	4654.11	0	0.4
1007	110.77	28.05	11.97	13.20	1.79	10.26	9.86	46.67	5169.80	0	0.1
1008	86.73	17.74	11.01	12.60	1.73	8.41	8.09	56.85	4930.93	0	0.2
1009	38.92	8.22	5.64	27.70	1.32	4.17	4.04	113.85	4430.99	0	12.4
1010	305.06	35.24	12.04	9.40	1.95	11.98	11.50	40.02	12207.23	0	1.6
1011	34.91	14.14	5.73	34.30	1.33	4.95	4.79	96.00	3351.21	0	0.2
1012	109.82	24.19	14.30	10.60	1.87	10.82	10.39	44.26	4860.23	0	0.4
1013	49.06	9.79	3.18	24.40	1.31	3.67	3.56	129.16	6336.75	0	1.7
1014	98.47	35.40	19.76	15.50	1.85	13.18	12.64	36.38	3582.23	0	0.2
1015	118.85	21.00	9.81	12.70	1.73	8 57	8.24	55.80	6631.43	0	0.3
1016	70.00	8.96	5.22	22.50	1.37	4.35	4.22	109.10	7637.26	0	7.9
40	6.34	8.05	4.40	32.00	1.25	3.66	3.55	129.48	820.92	0	1
41	1.29	1.87	1.10	110.00	0.78	0.97	0.99	465.66	600.70	0	1
42	4.43	6.27	3.30	35.00	1.18	2.92	2.85	161.16	713.93	0	0
43	3.17	2.82	1.70	60.00	0.94	1.51	1.50	306.67	972.14	0	1
44	1.14	2.26	1.20	43.00	0.96	1.29	1.29	355.44	405.20	0	0
45	7.11	8.55	4.40	19.00	1.39	4.13	4.01	114.73	815.73	0	0
63	0.02	0.27	0.12	160.00	0.51	0.18	0.25	1840.00	36.80	0	10
46	3.75	2.59	1.20	93.00	0.83	1.17	1.18	389.21	1459.52	0	1
47	1.72	2.73	1.40	68.00	0.90	1.35	1.35	340.95	586.43	0	0
48	1.49	1.46	0.70	120.00	0.72	0.73	0.76	606.44	903.60	0	1
49	0.29	0.88	0.40	130.00	0.65	0.48	0.52	887.96	257.51	0	0
50	0.34	1.03	0.50	65.00	0.77	0.63	0.66	692.29	235.38	0	0
51	1.04	2.55	1.50	82.00	0.87	1.30	1.30	352.71	366.82	0	2
52	2.36	4.18	2.40	60.00	1.00	2.00	1.97	233.47	550.99	0	0
53	0.47	1.56	0.80	90.00	0.78	0.83	0.86	537.07	252.42	0	0
54	12.49	11.06	7.40	37.00	1.31	4.90	4.74	97.01	1211.66	0	0
55	1.45	4.25	2.80	52.00	1.04	2.19	2.16	213.36	309.38	0	0
56	3.98	4.19	2.20	54.00	1.01	1.97	1.95	236.26	940.30	0	1
57	2.15	3.50	2.30	38.00	1.07	2.00	1.98	232.76	500.42	0	0
58	0.98	2.49	1.20	47.00	0.95	1.32	1.32	348.70	341.72	0	1
59	2.66	4.99	2.70	28.00	1.19	2.59	2.53	181.49	482.77	0	0
60	3.35	6.45	4.00	24.00	1.29	3.42	3.33	138.20	462.96	0	1
61	6.60	9.22	6.10	24.00	1.38	4.61	4.47	103.01	679.87	0	0
62	0.01	0.14	0.07	240.00	0.43	0.11	0.25	1840.00	18.40	0	0
64	1.08	1.95	1.20	19.00	1.10	1.43	1.42	323.10	348.95	0	4
65	4.43	2.81	1.50	70.00	0.90	1.39	1.39	330.71	1465.04	0	1
66	0.89	2.45	1.30	16.00	1.17	1.66	1.65	279.51	248.76	0	3
67	1.86	1.95	1.00	60.00	0.87	1.07	1.08	425.62	791.66	0	1
68	7.05	7.37	4.30	16.00	1.42	4.00	3.88	118.49	835.38	0	2
69	4.21	5.84	3.30	26.00	1.20	2.92	2.85	161.30	679.06	5	3
70	2.52	2.83	1.40	46.00	0.92	1.39	1.38	332.14	836.98	10	6
71	2.19	3.95	2.10	34.00	1.03	1.95	1.92	239.25	523.96	10	6
72	0.25	1.13	0.70	39.00	0.88	0.82	0.85	544.34	136.08	0	4
27	1.38	1.56	0.90	120.00	0.74	0.82	0.85	542.06	748.04	0	2
28	3.58	5.14	3.00	37.00	1.14	2.59	2.53	181.79	650.81	0	0
29	5.23	1.36	0.60	130.00	0.70	0.66	0.69	665.45	3480.28	0	1
30	1.71	2.98	1.50	28.00	1.02	1.60	1.59	290.07	496.02	10	10
31	0.79	1.54	0.80	50.00	0.82	0.87	0.89	514.39	406.37	10	5
32	0.32	0.93	0.50	46.00	0.60	0.48	0.52	888.29	284.25	50	25
23	2.93	1.97	1.10	48.00	0.92	1.16	1.17	393.46	1152.83	0	1
24	1.92	4.50	1.60	51.00	0.94	1.71	1.69	271.76	521.78	10	5
33	0.51	1.42	0.70	23.00	0.61	0.61	0.64	717.04	365.69	80	40
25	2.82	2.32	0.80	79.00	0.82	0.99	1.01	455.29	1283.91	0	1
26	11.45	8.34	4.50	6.00	1.68	5.00	4.83	95.19	1089.95	5	3

34	0.95	3.16	1.70	6.00	1.31	2.16	2.13	216.18	205.37	20	10
73	0.12	0.62	0.30	77.00	0.68	0.41	0.46	1006.79	120.81	0	4
74	13.91	12.08	7.00	23.00	1.42	5.37	5.19	88.64	1232.99	2	1
75	0.92	1.86	1.10	53.00	0.90	1.11	1.12	409.01	376.29	0	2
1	8.53	4.66	1.80	32.00	1.11	2.11	2.07	222.03	1893.88	0	1
2	0.67	2.00	1.00	1.00	1.92	2.36	2.32	198.62	133.07	0	0
3	0.70	1.38	0.70	32.00	0.82	0.81	0.84	548.37	383.86	20	10
4	0.49	0.75	0.40	130.00	0.54	0.37	0.42	1097.73	537.89	30	15
5	0.93	1.74	0.80	31.00	0.75	0.83	0.86	536.51	498.95	40	20
6	1.23	2.32	1.20	26.00	0.69	0.93	0.95	481.75	592.55	70	35
7	0.84	1.27	0.60	97.00	0.74	0.68	0.71	647.58	543.97	0	2
8	1.81	2.17	1.00	57.00	0.88	1.11	1.12	410.42	742.87	2	1
9	1.14	1.07	0.40	130.00	0.66	0.51	0.55	831.09	947.45	0	2
10	0.79	0.82	0.30	220.00	0.57	0.37	0.42	1102.77	871.19	2	6
11	0.78	1.62	0.90	72.00	0.81	0.91	0.93	493.88	385.23	2	1
12	0.75	1.30	0.60	62.00	0.76	0.70	0.73	628.08	471.06	10	5
13	0.51	1.10	0.40	59.00	0.64	0.50	0.54	847.26	432.10	30	15
14	1.23	2.88	1.50	52.00	0.90	1.40	1.40	329.08	404.77	10	7
15	0.49	1.09	0.70	32.00	0.86	0.79	0.82	563.36	276.05	10	5
16	2.01	2.73	1.60	50.00	0.86	1.33	1.33	345.00	693.45	20	10
17	0.33	1.23	0.60	76.00	0.57	0.52	0.56	827.07	272.93	50	25
18	0.46	1.26	0.70	50.00	0.59	0.56	0.60	765.11	351.95	60	30
19	1.20	2.63	1.40	62.00	0.76	1.13	1.14	404.63	485.55	30	15
20	0.37	1.36	0.70	37.00	0.85	0.84	0.86	534.42	197.73	10	5
21	2.54	4.16	2.20	16.00	0.94	1.83	1.81	254.24	645.76	50	25
22	0.62	1.85	0.90	110.00	0.77	0.89	0.92	502.28	311.42	0	0
76	1.27	2.79	1.30	17.00	1.17	1.72	1.71	269.42	342.16	0	2
77	5.22	4.53	2.40	40.00	1.09	2.23	2.19	210.15	1096.96	0	1
78	3.34	4.50	2.50	28.00	1.17	2.42	2.37	194.14	648.43	0	0
79	6.35	4.53	2.20	36.00	1.10	2.20	2.16	212.85	1351.59	0	1
80	2.20	4.37	2.70	27.00	1.18	2.48	2.43	189.43	416.74	0	0
81	4.10	3.23	2.00	45.00	1.02	1.78	1.77	260.56	1068.29	0	1
82	4.40	4.56	3.00	30.00	1.17	2.57	2.52	182.80	804.34	0	0
83	0.05	0.53	0.20	65.00	0.67	0.34	0.39	1176.71	58.84	0	0
84	9.48	7.24	2.70	32.00	1.19	2.91	2.84	161.88	1534.67	0	0
85	2.34	2.05	1.10	70.00	0.86	1.10	1.11	415.25	971.69	0	1
86	5.44	6.22	2.70	34.00	1.16	2.72	2.65	173.32	942.84	0	0
87	9.67	7.01	3.50	4.00	1.81	4.73	4.58	100.46	971.45	0	1
88	15.42	9.09	5.20	30.00	1.30	4.13	4.01	114.73	1769.18	0	0
89	1.52	1.80	0.80	47.00	0.89	1.00	1.01	454.33	690.58	0	1
90	6.64	7.12	4.40	40.00	1.19	3.34	3.25	141.42	939.01	0	0
91	2.15	2.60	1.30	53.00	0.94	1.35	1.35	340.74	732.59	0	1
92	15.46	8.26	4.70	32.00	1.26	3.79	3.68	125.09	1933.82	0	0
93	2.62	4.13	1.90	41.00	1.05	1.96	1.93	238.31	624.37	0	1
94	2.34	2.63	1.30	69.00	0.89	1.29	1.29	356.06	833.17	0	1
95	3.54	4.57	2.50	49.00	1.05	2.18	2.15	214.24	758.41	0	0
96	5.57	6.65	4.40	35.00	1.21	3.34	3.25	141.50	788.14	0	1
97	1.61	2.11	1.00	70.00	0.85	1.07	1.08	425.35	684.81	0	1
98	2.25	3.28	1.90	30.00	1.10	1.90	1.88	244.96	551.16	0	0
99	3.33	2.83	1.40	59.00	0.93	1.40	1.40	327.87	1091.79	0	1
100	13.44	8.88	4.90	27.00	1.32	4.09	3.96	116.04	1559.63	0	0
101	8.43	6.49	2.70	40.00	1.13	2.67	2.62	175.85	1482.41	0	3
102	6.86	4.68	2.60	46.00	1.07	2.26	2.22	206.83	1418.83	0	1
103	6.51	5.14	2.00	24.00	1.20	2.40	2.36	195.09	1270.04	0	1
104	3.62	4.88	2.10	24.00	1.19	2.40	2.36	195.32	707.05	0	1
105	3.44	4.46	2.40	30.00	1.15	2.34	2.30	200.34	689.16	0	0
106	3.03	2.33	1.30	48.00	0.95	1.32	1.32	348.30	1055.35	0	1
107	2.72	3.68	2.00	46.00	1.03	1.87	1.85	249.29	678.08	0	0
108	2.97	4.52	2.30	44.00	1.03	2.09	2.05	224.06	665.45	5	3
109	1.28	1.78	0.60	50.00	0.86	0.88	0.90	511.29	654.45	0	1
110	0.97	1.53	0.70	55.00	0.84	0.86	0.89	519.53	503.95	0	1
111	1.65	3.18	1.90	31.00	1.02	1.76	1.74	264.47	436.38	10	5
112	2.06	4.69	3.10	35.00	1.14	2.55	2.50	183.91	378.86	0	0
113	4.20	6.54	4.30	29.00	1.25	3.41	3.32	138.64	582.27	0	0
114	5.01	5.16	2.80	40.00	1.11	2.48	2.43	189.00	946.90	0	1
115	1.55	2.54	0.90	61.00	0.88	1.13	1.14	403.04	624.71	0	0
116	1.02	1.23	0.50	86.00	0.74	0.64	0.67	683.34	697.00	0	1
117	1.18	2.05	1.20	59.00	0.89	1.17	1.18	390.09	460.31	0	0
118	2.19	2.91	1.50	43.00	1.00	1.55	1.54	298.57	653.87	0	1
119	3.91	5.89	3.10	26.00	1.23	2.95	2.88	159.74	624.58	0	0

120	2.49	2.50	1.20	53.000.93	1.29	1.29	355.90	886.20	0	1
121	5.70	4.99	2.20	31.001.14	2.35	2.30	199.68	1138.15	0	1
122	1.41	3.03	2.00	37.001.05	1.81	1.79	257.31	362.80	0	0
123	2.32	2.75	1.60	41.001.01	1.57	1.56	295.10	684.63	0	1
124	2.50	3.47	1.70	32.001.08	1.84	1.82	253.00	632.49	0	0
125	1.84	3.40	2.10	33.001.09	1.97	1.94	237.06	436.20	0	0
126	7.58	4.49	2.50	40.001.09	2.26	2.22	207.66	1574.06	0	1
127	4.21	2.76	1.50	60.000.93	1.42	1.42	323.62	1362.46	0	1
128	0.70	1.59	0.80	62.000.84	0.90	0.92	499.16	349.42	0	0
129	3.19	3.16	1.70	56.000.96	1.59	1.58	290.39	926.34	0	2
130	2.26	4.32	2.10	45.001.05	2.03	2.00	229.75	519.24	0	0
131	2.49	4.57	2.10	40.001.08	2.12	2.09	220.13	548.12	0	0
132	3.20	4.28	2.70	56.001.03	2.14	2.10	218.70	699.84	0	0
133	5.26	7.20	3.80	29.001.25	3.37	3.28	140.07	736.79	0	0
134	4.12	3.64	1.60	57.000.97	1.64	1.63	282.79	1165.11	0	1
135	1.72	1.91	1.20	80.000.84	1.07	1.09	422.90	727.39	0	1
136	3.08	6.08	3.60	41.001.15	2.90	2.83	162.54	500.64	0	0
137	0.12	0.72	0.40	110.000.66	0.46	0.50	923.62	110.83	0	0
138	1.97	3.97	2.30	47.001.04	2.02	1.99	231.06	455.18	0	0
139	1.73	2.76	1.30	67.000.90	1.32	1.32	347.97	601.99	0	0
140	2.98	4.36	1.80	41.001.04	1.93	1.91	241.14	718.59	2	1
141	2.04	3.66	2.00	62.000.97	1.76	1.74	263.98	538.51	0	1
142	4.38	3.90	2.10	55.001.00	1.88	1.86	247.68	1084.85	0	1
143	3.85	3.33	1.70	25.001.13	1.90	1.87	245.41	944.82	0	0
144	6.02	8.46	3.30	32.001.21	3.30	3.21	143.32	862.81	2	1
145	12.03	11.14	5.70	12.001.59	5.52	5.33	86.30	1038.13	0	0
146	15.30	7.09	2.50	31.001.19	2.82	2.76	166.94	2554.15	0	1
147	1.80	2.70	1.80	73.000.91	1.46	1.45	316.32	569.37	0	0
148	4.31	4.81	2.40	42.001.08	2.26	2.22	207.38	893.80	0	1
149	4.10	3 11	1.90	61.000.95	1.63	1.62	284.83	1167.79	0	0
150	7.66	5.45	2.80	42.001.11	2.51	2.46	186.88	1431.47	0	1
151	7.64	5.64	2.00	30.001.15	2.39	2.34	196.46	1500.95	0	0
152	24.20	13.06	6.90	22.001.46	5.62	5.43	84.77	2051.49	0	0
153	0.76	2.98	2.00	34.001.07	1.83	1.80	254.88	193.71	0	0
154	0.61	1.81	0.90	100.000.78	0.90	0.92	497.68	303.58	0	0

NOTE: 640 CP = 460; TR = 0.25 hours; and PERCENT SAND = 100; for all of the subbasins.

Flood hydrographs were computed and routed for the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year frequency and the SPF events. A total storm duration of 24 hours was used for the frequency-related events. The resultant peak discharges were tabulated at each point of interest. The expected probability percent exceedance frequency relationships for each discharge location were determined by recomputing the plotting positions for each computed peak discharge, based on a 40-year adjustment.

MODEL CALIBRATION DURING RECONNAISSANCE STUDY

Flood hydrograph reproductions were not attempted during this phase of study. All reservoirs, including the numerous SCS floodwater retarding projects, were assumed to have their conservation pools filled prior to the onset of the hypothetical flood events. Initially, the statistically developed frequency versus discharge relationship, which was computed for the USGS streamflow gagesite "Pecan Bayou at Brownwood", was assumed to be reasonable. This particular gage record was continuous from the point in time when Lake Brownwood went into normal operation (1934) until water year 1983. The systematic record and resultant frequency versus discharge relationship are presented earlier in this narrative, under the section "Streamflow and Reservoir Storage Gaging Stations". Rainfall loss rates were adjusted in a trial-and-error fashion until the watershed runoff model could simulate the statistically computed frequency curve (disregarding partial duration adjustments for the more frequent events), as shown in Table A-17.

TABLE A-17

ATTEMPTED "FREQUENCY CURVE CALIBRATION" RESULTS

ANNUAL EXCEEDANCE PROBABILITY	EFFECTIVE RECURRENCE INTERVAL (years)	DEFAULT SANDY SOIL INFILTRATION RATE (iph)	"CALIBRATED" SANDY SOIL INFILTRATION RATE (iph)	PEAK DISCHARGE AT BROWNWOOD GAGESITE (cfs)	RESULTING PEAK POOL ELEVATION ON LAKE BROWNWOOD (feet NGVD)
0.500	1	0.26	0.15	1000	1425.9
0.500	2	0.26	0.15	4000	1426.5
0.200	5	0.21	0.18	12000	1429.6
0.100	10	0.18	0.32	18000	1431.3
0.040	25	0.15	0.38	29000	1433.5
0.020	50	0.13	0.43	37000	1435.0
0.010	100	0.10	0.47	47000	1436.7
0.002	500	0.08	0.63	68000	1439.5

Such extreme loss rates were not felt to be reasonable, especially for the rarer flood events. Upon further research of both recent and historic flood records, it was noted that the ungaged flow events of 1990 and 1991 were of sufficient magnitude to significantly alter the statistical frequency curve. Similarly, the extreme event of 1932, which was effectively "controlled" by a then empty Lake Brownwood, would have otherwise had a major impact. In fact, Lake Brownwood has often provided some degree of incidental flood control for Brownwood, since the pool level has had a general tendency to reside below the spillway crest prior to the occurrence of significant inflows. As mentioned earlier, the spillway has been overtopped in only 25 of the 39 water years within the 1948-1986 period of USGS records. As a result, the annual series of maximum discharges at the Brownwood gage is comprised of a combination of both basinwide and localized (downstream of Lake Brownwood Dam) runoff events. The intervening drainage area between the gagesite and the dam covers about 88 square miles.

Due to concerns with the applicability of the statistical frequency relationships at both Lake Brownwood and the city, and the fact that sufficient resources were not available to perform actual flood hydrograph reproductions during this phase of study, the decision was made to apply the more standard rainfall loss rates for sandy soils, and adopt the watershed runoff modeling results.

The summary of existing conditions, expected probability, peak discharges and the resulting peak pool elevations on Lake Brownwood are provided in Tables A-18 and A-19. For economic evaluation purposes, peak discharges for the "1000-year" recurrence interval flood were estimated, by extrapolating the discharge versus frequency curve at each tabulated point.

The SWFHYD (Southwestern Division, Fort Worth District - Hydrology Package) computer program was used to compute the synthetic rainfall, runoff volumes, unit hydrographs, and flood hydrographs. This program was also used to route the flood hydrographs downstream and to tabulate the peak discharges. The input data files are provided in Table A-20, at the end of this appendix.

TABLE A-18

EXPECTED PROBABILITY PEAK DISCHARGES EXISTING, WITHOUT-PROJECT CONDITIONS

NOTE: The "1000-Year" values were graphically extrapolated.

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq.miles)	EFFECTIVE RECURRENCE INTERVAL (years)								
		1	2	5	10	25	50	100	500	1000
		ANNUAL EXCEEDANCE PROBABILITY								
		NA	0.500	0.200	0.100	0.040	0.020	0.010	0.002	0.001
Pecan Bayou:										
At State Highway 573	2084	1000	8000	27000	38000	54000	75000	108000	175000	215000
Below Blanket Creek	2083	1000	8000	27000	38000	54000	75000	108000	175000	215000
Above Blanket Creek	1887	1000	6000	18000	25000	44000	63000	91000	148000	182000
Below Rough Creek	1881	1000	6000	18000	26000	44000	63000	91000	148000	182000
Below Fisk Creek	1866	1000	6000	19000	26000	44000	63000	91000	148000	182000
Below Long Branch	1849	1000	6000	19000	26000	44000	63000	91000	148000	182000
Below Pecan Creek	1840	1000	6000	18000	26000	43000	63000	91000	148000	182000
Below Mackinally Creek	1831	1000	7000	20000	28000	43000	63000	91000	148000	182000
Below Devils River	1813	1000	6000	19000	27000	43000	62000	91000	148000	182000
Below Doudle Creek	1805	1000	6000	19000	27000	43000	62000	90000	148000	183000
Below Lewis Creek	1780	2000	7000	19000	26000	43000	62000	91000	148000	182000
Below Steppes Creek	1772	2000	6000	18000	25000	43000	62000	91000	148000	182000
Above Steppes Creek	1737	2000	5000	16000	24000	43000	62000	90000	148000	183000
Below Willis Creek	1736	2000	5000	16000	24000	43000	62000	90000	148000	183000
Above Willis Creek	1707	1000	5000	15000	24000	43000	62000	90000	147000	181000
Below Delaware Creek	1707	1000	5000	16000	24000	43000	62000	90000	147000	181000
Above Delaware Creek	1693	1000	4000	14000	24000	43000	61000	89000	147000	182000
Below Adams Branch	1693	1000	4000	14000	24000	43000	61000	90000	147000	181000
Above Adams Branch	1659	1000	3000	11000	24000	42000	61000	89000	146000	181000
At U.S. Highway 377	1654	1000	4000	11000	24000	42000	61000	89000	147000	182000
Below Salt Creek	1634	1000	3000	11000	24000	42000	61000	89000	147000	182000
Above Elm Creek	1572	1000	2000	10000	23000	42000	61000	89000	146000	181000
Below Lake Brownwood Dam	1566	1000	2000	10000	23000	42000	61000	89000	146000	181000
South Willis Creek:										
Below Country Club Trib.	5.36	281	1250	3080	3860	4760	5540	6300	8160	9130
At Morris Sheppard Drive	6.11	330	1434	3080	3940	5180	6080	6940	9190	10400
Above Krueger Hill Trib.	6.62	318	1380	3050	3950	5170	6250	7220	9870	11300
Below Krueger Hill Trib.	7.85	407	1710	3880	5000	6460	7710	8920	12100	13800
Above River Oaks Drive Trib.	8.34	407	1740	3870	4940	6160	7310	8540	11900	13800
Below River Oaks Drive Trib.	10.35	567	2300	5230	6650	8230	9730	11300	15900	18400
Above Willis Creek	10.68	581	2310	5150	6540	8190	9720	11400	15800	18200
Willis Creek:										
Below SCS Damsite BL#3	9.20	55	110	124	131	137	141	184	2300	????
At U.S. Highway 377	9.90	89	320	735	931	1180	1350	1530	1940	2150
At Railroad Spur	10.39	141	457	1020	1320	1750	2030	2320	2960	3200
At Custer Road	11.32	251	726	1630	2070	2600	3020	3450	4570	5000
Above South Willis Creek	12.55	400	934	2080	2660	3340	3910	4480	5760	6300
Below South Willis Creek	23.23	818	2920	6760	8560	10700	12700	14800	20200	22300
Above Oakpark Drive Trib.	23.69	811	2850	6480	8080	9850	11500	13700	19700	22300
Below Oakpark Drive Trib.	24.89	906	3150	7120	8790	10700	12400	14700	21500	24300
Above Lion Stadium Trib.	25.26	808	2780	6660	8410	10300	11900	14000	19700	22000
Below Lion Stadium Trib.	27.80	1060	3370	7950	10000	12300	14200	16600	23300	26000
Above Pecan Bayou	28.42	1040	3320	7910	10000	12400	14300	16700	23400	26200

TABLE A-19

PEAK POOL ELEVATIONS ON LAKE BROWNWOOD EXISTING, WITHOUT-PROJECT CONDITIONS

NOTE: The following elevation values are in feet, National Geodetic Vertical Datum (NGVD). They reflect the pool levels necessary to pass the previously tabulated expected probability peak discharges through the emergency spillway.

EFFECTIVE RECURRENCE INTERVAL (years)								
1	2	5	10	25	50	100	500	1000
ANNUAL EXCEEDANCE PROBABILITY								
NA	**0.500**	**0.200**	**0.100**	**0.040**	**0.020**	**0.010**	**0.002**	**0.001**
1425.9	1426.3	1429.8	1433.0	1436.5	1439.3	1442.8	1449.4	1452.1

PROJECTS INVESTIGATED DURING RECONNAISSANCE STUDY

A variety of flood control alternatives were considered by the study team during the reconnaissance and feasibity phases. In the case of South Willis Creek, channel modifications were investigated in some detail only during the reconnaissance phase of study. The existing conditions analyses indicated that one short reach might sustain enough equivalent annual damage to support an economically feasible solution. However, upon further investigation, this potential project area was eliminated from consideration, due to the lack of economic feasibility.

Channelization alternatives were investigated along Willis Creek during both study phases. The numerous residential properties situated just slightly above channel bank levels were found to produce enough expected annual flood damage to support a variety of potential solutions. Details on the investigated channel plan along Willis Creek are provided in the Hydraulics Analysis Appendix and within the main narrative of the Feasibility Report.

Channelization alternatives, including overflow swales were considered along Pecan Bayou during both study phases. Under present conditions, significant flood flows are normally passed along a series of sloughs and tributary channels in the right overbank area of the Pecan Bayou floodplain. Therefore, prime consideration was given to enhancing the hydraulic efficiency of this general flow path, from just north of US Highway 377 to near the ATSF RR bridge southeast of the city. As the reconnaissance study was nearing completion, this particular alternative had not been fully optimized to the point that it could clearly demonstrate the existence of an economically feasible solution. Therefore, a direct (on existing channel centerline) channel enlargement scheme was investigated and presented in the Reconnaissance Report. It was anticipated that the floodway swale approach, often referred to as a "diversion" channel plan, would be shown as being highly competitive, economically, during the feasibility study phase. Such an alternative would be much less impacting upon environmental resources than a main channel project, since the existing Pecan Bayou channel area is of fairly high habitat value for a wide variety of aquatic, terrestrial, and aviary species. Actual details on the investigated channel plan are provided in the Hydraulics Analysis Appendix and within the main narrative of the Feasibility Report.

Flood damage reduction for properties along Pecan Bayou and around Lake Brownwood could also be obtained via upstream floodwater detention. Under existing conditions, the expected pool levels shown in Table A-19 and peak discharges shown in Table A-18, were found to result in expected annual damages of about three million dollars at Lake Brownwood and about one million dollars within the city. This estimated total annual damage, when converted to a "first project cost" equivalent would appear to support a floodwater detention project costing up to about forty million dollars. Upon discovering these magnitudes of supportable project cost, the study team went into an intensive mode of investigation of detention alternatives during the reconnaissance phase of study, but were nonetheless unable to identify an economically feasible detention plan. Therefore, upstream detention alternatives were not considered further, during the subsequent feasibility phase of study.

As mentioned earlier in this writeup, the overall watershed upstream from the Lake Brownwood damsite is evenly split, about 800 square miles each, between the upper Pecan Bayou watershed segment and that for Jim Ned Creek. Since runoff from the Jim Ned Creek watershed is already considerably affected by Lake Coleman, Hords Creek Lake, and the numerous SCS floodwater retarding structures, the decision was made to concentrate on the upper Pecan Bayou watershed, which is affected in a more minor fashion by Lake Clyde and other SCS floodwater retarding structures.

Potential detention sites were determined through visual inspection of the standard 1:24,000 scale USGS topographic contour maps entitled: "Byrds", "Burkett", "Webbville", and "Crooked Creek". Several potential damsites were noted from just below the confluence of Hog Creek, actually within the headwaters of Lake Brownwood, to upstream of the confluence of Burnt Branch. Since the total drainage area upstream from Burkett is only slightly in excess of 400 square miles (one fourth of that which contributes to Lake Brownwood), projects above that point were eliminated from further consideration. Damsite centerline profiles and ponded surface area/reservoir storage capacity versus elevation relationships were developed for nine remaining sites. Upon further inspection it was noted that the first two sites downstream from Burkett could also be eliminated from consideration, since the total available reservoir storage capacity below the elevation which would induce damages within Burkett would not be sufficient to provide significant enough flood wave attenuation along Pecan Bayou. The damsite centerline profiles of the remaining project locations were used to develop estimates of the embankment fill quantities. Two primary locations, one upstream and the other downstream from the confluence of Hog Creek, were then selected for more detailed analysis.

The upper damsite was initially favored. It is located about 4,300 feet west of FM 2559, about 7,000 feet northwest of Byrds. The total drainage area at this point is about 654 square miles. There was concern over environmental impacts of altering the hydrologic/hydraulic characteristics of low flows in the reach immediately upstream from the damsite. Streamflow gaging records from the gagesite "Pecan Bayou near Cross Cut", for the period 1968-1978, were assessed to determine the relative occurrence frequencies of various mean daily flows. That particular gagesite is located further upstream, where the contributing drainage area is only about 555 square miles; therefore, its mean daily flow values were increased by 18 percent, to better reflect expected values at the potential damsite location. While the relatively short 10 years of record would not have been adequate to reasonably assess rare events, it was felt adequate for assessment of the more frequent event ranges. This analysis showed that the mean daily flow was less than 1,000 cfs more than 99 percent of the days of total record. Similarly, it was less than 500 cfs more than 98 percent of the time, and less than 100 cfs more than 97 percent of the time. Considering just the wetter period of April-May, the mean daily flow was less than 1,000 cfs about 99 percent of those times, and less than 200 cfs about 95 percent of those times. For simple comparison purposes, the peak instantaneous flow on record was 16,200 cfs, on 4 August 1978, while the peak mean daily value for that event was 6,160 cfs. After careful consideration of issues related to expected environmental impacts resulting from the temporary floodwater storage at the potential "dry detention" damsite, it was decided to provide for low flow passage of at least 500 cfs, and preferably 1,000 cfs. An uncontrolled culvert, mounted at the invert of Pecan Bayou, was built into the embankment project design.

The initial damsite was tested hydrologically, to determine the required overflow weir heights for containment of a variety of frequency related inflow events. The 5-, 10-, and 25-year frequency pool levels were ascertained with application of a 5-foot diameter round concrete pipe culvert for passage of the low flows. This scenario resulted in pool levels of 1458, 1474, and 1491 feet NGVD, respectively. For simplification purposes, the main embankment was assumed to consist of roller compacted concrete, with an emergency spillway sill positioned across the deeper portion of the valley. Overall economics of this plan were assessed by relating with-project pool levels on Lake Brownwood to the single event flood damages which had been determined for the given existing conditions pool levels, for the 1-year through 1000-year recurrence interval flood events. Additionally, the relationship between peak discharges and single event flood damages at Brownwood was used to develop estimates of flood damage reduction benefits to that damage center. The three previously mentioned project sizes resulted in expected benefits of about 1.3-, 2.1-, and 2.6-million dollars annually. Supportable "first costs" were then estimated by applying the equal payment series interest factor to these annual damage values, based on a 50-year economic life. This factor, which is approximately 10:1, results in supportable first cost of 13-, 21-, or 26-million dollars, respectively. Unfortunately, as anticipated implementation costs were being developed late in the reconnaissance study phase, it became apparent that such projects would cost considerably more than what the expected benefits could ever support. A larger diameter low flow culvert was tested, in hopes of better controlling the peaks of the more rare events, by assuring that the dry detention pool level was as low as possible prior to the major inflow peak. The annual benefits for a 10-foot diameter culvert plan were 1.3-, 2.0-, and 2.4-million dollars, respectively. These minor increases would not be sufficient to make the plan economically feasible.

It was noted that the more downstream damsite, just below the confluence of Hog Creek, would be capable of collecting runoff from an additional 90 square miles of drainage area. This site was tested similarly to that in the preceding paragraph. The 5-foot diameter low flow culvert scenario resulted in emergency spillway weir crest elevations of 1451, 1466, and 1482 feet NGVD, respectively, for the 5-, 10-, and 25-year frequency inflow events. Annual benefits of about 1.4-, 2.4-, and 3.0-million dollars were estimated to result with these three plans. These increases, though significant, would not make up for the additional costs associated with constructing an embankment across the generally swampy headwater reach of Lake Brownwood and other costs relating to increased real estate requirements.

The civil design study team member performed a cursory test to determine if use of earthen embankments, with concrete applied only to the spillway portions, would improve the potential projects' economy. He discovered that the costs for just the earthfill component of the overall embankment costs would exceed the expected supportable first costs. As a final test, the more downstream detention site was assumed to have an infinite embankment height, with passage of floodwaters being allowed only through a 5-foot diameter culvert. This "maximum benefits" scenario was found to produce expected annual benefits of about 3.5 million dollars and could support a 35 million dollar project. Based on these findings, it may have been unreasonable to assume that dry detention along Pecan Bayou, upstream of Lake Brownwood has any economic viability.

It is assumed that investigations of detention projects on Jim Ned Creek would result in similar findings, since its watershed is of about the same size and shape as Pecan Bayou. Adequate detention sites do not exist between the Lake Brownwood dam and the city of Brownwood.

Alterations at Lake Brownwood itself, allowing for a rapid depletion of storage preceding major inflow events, may be economically viable. This type of plan would require a major modification at either the Lake Brownwood dam or spillway and the installation of a soundly configured streamflow/precipitation gaging network throughout the Pecan Bayou watershed above Brownwood. However, this type of alternative was not included in the scope for the subsequent feasibility study.

NEW USACE POLICY FOR REPORTING FLOOD FREQUENCIES

During the interim since completion of the Reconnaissance Study, USACE's Office of the Chief of Engineers (OCE) provided new guidance regarding the method of reporting the annual exceedance probabilities for the more rare flood events. The previous method resulted in the assignment of an "expected probability" for each event, as shown in Table A-18. This type of array provides for a slightly skewed frequency curve, when compared to the function directly computed via the watershed runoff modeling. This so-called "expected probability" adjustment was meant to account for the likelihood that the uncertainty (the error distribution) in peak discharge magnitude is generally skewed in the upward direction. However, as USACE developed procedures for measuring flood damage reduction benefits based on application of parameter-specific uncertainty analyses, it became necessary to forego this adjustment. Under the new criteria, the flood damage associated with each stage, the hydraulic stage associated with each discharge, and the peak discharge associated with each frequency are assigned measures of uncertainty, based on a predicted standard deviation of parameter magnitude about the directly computed function. These uncertainty functions are subsequently applied within a Monte Carlo statistical evaluation scheme, in order to estimate expected flood damages. Since this intensive solution technique theoretically accounts for any anticipated skew in the expected uncertainty of hydrologic peak discharges, it is now necessary to report the so-called "computed probability" function. It is merely the original set of results from the watershed runoff modeling, prior to having been adjusted for "expected probability".

MODEL CALIBRATION DURING FEASIBILITY STUDY

During the interim since completion of the Reconnaissance Study, no significant amount of additional watershed runoff data became available for the general Pecan Bayou watershed. Therefore, the rainfall-runoff modeling developed during the reconnaissance phase of study was also applied in the feasibility phase of study. The tabulated results along Pecan Bayou, as shown in Table A-20, were altered only to reflect the previously mentioned change in USACE policy. However, in the case of the Willis Creek watershed, additional efforts were made to address the substantial differences between peak discharges developed during the civil works planning study and those represented in the effective FEMA FIS.

The hydrologic analyses used in the FIS were performed by the private firm of Bovay Engineers, Inc., in the late 1970's. A summary of the FIS peak discharges is provided in Table A-9. In terms of the predicted "100-year" peak discharges on Willis Creek, below the mouth of South Willis Creek, the effective FIS indicates a value of 4,091 cfs, in comparison to the Reconnaissance Study value of 12,195 cfs (in "computed probability" format). The total drainage area at this point is approximately 23.23 square miles, but approximately 11.18 square miles within this basin are at least partially controlled by three SCS floodwater retarding structures. Above the mouth of South Willis Creek, the effective FIS indicates a value of 1,087 cfs, in comparison to the Reconnaissance Study value of 3,778 cfs (in "computed probability" format). The total drainage area at this point is approximately 12.55 square miles, but approximately 9.20 square miles within this basin are at least partially controlled by an SCS floodwater retarding structure.

Comparisons were also made with results obtained by applying the Texas Department of Transportation (TXDOT) regionalized regression equations, which were developed by the USGS in the late 1970's. The subject site is located near the intersection of three of the USGS's six defined regions in the state of Texas. These include: Region II, extending eastward from the study area; Region III, extending southwestward from the study area, and Region IV, extending northwestward from the study area. In this investigation, the portion of contributing drainage area situated above the SCS floodwater retarding structures was excluded as being non-contributing.

However, anticipated releases through the applicable principal spillway structures were added to the results computed with the regression equations, in order to reflect total peak discharges at each point of interest. Again in terms of the "100-year" peak discharges, the supplemented TXDOT regression equation results range from 5,751 to 8,508 cfs, and average 7,001 cfs, below the mouth of South Willis Creek. Similarly, the results range from 2,541 to 3,331 cfs, and average 2,993 cfs, above the mouth of South Willis Creek.

The decision was made to investigate streamflow gaging records throughout the region. All gaging sites: on watersheds having drainage areas less than 100 square miles; located within 75 miles of Brownwood; having at least 10 years of systematic records; and minimally affected by floodwater impoundment structures were included. Thirty-seven sites met the drainage area and distance criteria, but only seventeen of them had more than 10 years of systematic records, and only six of them were minimally affected by floodwater impoundments. Sites meeting the criteria included: Little Elm Creek near Abilene; North Fork of Hubbard Creek near Albany; Big Cedar Creek near Ivan; Pecan Creek near San Angelo; Hords Creek near Valera; and Hords Creek near Coleman. In the case of the Hords Creek gaging sites, only the contributing drainage area situated downstream from USACE' Hords Creek Dam was considered. Projected "100-year" frequency results at these gaging site vary considerably, but when the individual curves are treated as a group, it suggests a peak discharge on the order of 1,000 cfs per square mile of contributing drainage area. When applied to Willis Creek, this would relate to total "100-year" peak discharges of about 12,400 and 3,500 cfs, below and above the mouth of South Willis Creek, respectively. Again, the Reconnaissance Study results were 12,195 and 3,778 cfs, respectively, when presented in "computed probability" format.

Based upon these findings, the decision was made to retain the use of the unit hydrograph lagging times, initial abstractions, and infiltration rates, that were applied during the reconnaissance phase of study, for the "100-year" frequency flood event. However, during early stages of the plan formulation process, concerns arose that the frequency at which substantial flood damage ensues was somewhat overstated; therefore, an adjusted relationship between infiltration rate and frequency was adopted for the Willis Creek watershed. In this particular instance, the "1-year" infiltration rate was raised to an extreme value of 1.00 iph, the "100-year" infiltration rate was held at a value of 0.10 iph, and the "1000-year" infiltration rate was assigned a modest value of 0.05 iph. A smooth overall function was developed, resulting in: a "2-year" value of 0.93 iph; a "5-year" value of 0.66 iph; a "10-year" value of 0.35 iph; a "25-year" value of 0.19 iph; a "50-year" value of 0.14 iph; and a "500-year" value of 0.06 iph. These adjustments provide for a general compromise between the higher USACE results and the lower FEMA FIS results, but only for the more frequent flood events.

The adjusted summary of existing condition, computed probability, peak discharges is provided in Table A-20. The SWFHYD (Southwestern Division, Fort Worth District - Hydrology Package) computer program was used to compute the synthetic rainfall, runoff volumes, unit hydrographs, and flood hydrographs. This program was also used to route the flood hydrographs downstream and to tabulate the peak discharges. The adjusted input data file is provided in Table A-21, at the end of this appendix.

TABLE A-20

COMPUTED PROBABILITY PEAK DISCHARGES EXISTING, WITHOUT-PROJECT CONDITIONS

		EFFECTIVE RECURRENCE INTERVAL (years)								
	DRAINAGE	1	2	5	10	25	50	100	500	1000
FLOODING SOURCE	AREA		ANNUAL EXCEEDANCE PROBABILITY							
AND LOCATION	(sq.miles)	NA	0.500	0.200	0.100	0.040	0.020	0.010	0.002	0.001
Pecan Bayou:										
At State Highway 573	2084	7000	16000	30000	42000	56000	74000	97000	159000	215000
Below Blanket Creek	2083	7000	16000	30000	42000	56000	74000	97000	159000	215000
Above Blanket Creek	1887	5000	11000	19000	33000	52000	70000	92000	150000	182000
Below Rough Creek	1881	5000	11000	19000	33000	52000	70000	92000	150000	182000
Below Fisk Creek	1866	5000	11000	20000	33000	52000	70000	92000	151000	182000
Below Long Branch	1849	5000	11000	20000	33000	52000	70000	92000	151000	182000
Below Pecan Creek	1840	5000	11000	20000	33000	52000	70000	92000	151000	182000
Below Mackinally Creek	1831	5000	12000	21000	33000	52000	70000	92000	151000	182000
Below Devils River	1813	5000	11000	21000	33000	52000	70000	92000	151000	182000
Below Doudle Creek	1805	5000	11000	20000	33000	52000	70000	91000	151000	183000
Below Lewis Creek	1780	6000	12000	20000	33000	52000	70000	92000	151000	182000
Below Steppes Creek	1772	5000	11000	19000	33000	52000	70000	92000	151000	182000
Above Steppes Creek	1737	4000	9000	17000	32000	51000	69000	91000	151000	183000
Below Willis Creek	1736	4000	9000	17000	32000	51000	69000	91000	151000	183000
Above Willis Creek	1707	4000	8000	17000	32000	51000	69000	91000	150000	181000
Below Delaware Creek	1707	4000	9000	17000	32000	51000	69000	91000	150000	181000
Above Delaware Creek	1693	3000	8000	17000	32000	51000	68000	91000	150000	182000
Below Adams Branch	1693	3000	8000	17000	32000	51000	68000	91000	150000	181000
Above Adams Branch	1659	3000	6000	17000	32000	50000	68000	90000	150000	181000
At U.S. Highway 377	1654	3000	6000	17000	32000	50000	68000	90000	151000	182000
Below Salt Creek	1634	3000	6000	17000	32000	50000	68000	90000	151000	182000
Above Elm Creek	1572	1000	4000	17000	31000	50000	67000	90000	150000	181000
Below Lake Brownwood Dam	1566	1000	4000	17000	31000	50000	67000	90000	151000	181000
South Willis Creek:										
Below Country Club Trib.	5.36	281	1250	3010	3790	4610	5360	5960	7700	9800
At Morris Sheppard Drive	6.11	67	948	2320	3390	4870	5850	6550	8680	11200
Above Krueger Hill Trib.	6.62	105	925	2340	3380	4810	5980	6770	9260	11800
Below Krueger Hill Trib.	7.85	137	1135	2920	4290	6040	7400	8360	11400	14600
Above River Oaks Drive Trib.	8.34	140	1160	2950	4265	5790	7000	7975	11200	14700
Below River Oaks Drive Trib.	10.35	226	1555	3980	5800	7770	9330	10600	14800	19100
Above Willis Creek	10.68	249	1560	3940	5670	7680	9310	10600	14800	19200
Willis Creek:										
Below SCS Damsite BL#3	9.20	7	106	118	126	135	140	144	1600	6810
At U.S. Highway 377	9.90	42	229	566	820	1125	1310	1450	1850	6930
At Railroad Spur	10.39	81	347	787	1140	1630	1960	2190	2820	6980
At Custer Road	11.32	165	550	1260	1840	2460	2920	3250	4310	6840
Above South Willis Creek	12.55	325	750	1610	2360	3160	3760	4230	5480	6710
Below South Willis Creek	23.23	551	2000	5080	7410	10100	12100	13900	19000	24600
Above Oakpark Drive Trib.	23.69	529	1940	4880	7040	9320	11000	12700	18300	24100
Below Oakpark Drive Trib.	24.89	607	2140	5380	7690	10100	11900	13700	19900	26100
Above Lion Stadium Trib.	25.26	523	1850	4940	7270	9770	11400	13100	18400	24400
Below Lion Stadium Trib.	27.80	739	2280	5880	8690	11600	13600	15500	21800	28700
Above Pecan Bayou	28.42	727	2230	5800	8640	11700	13700	15600	21900	28800

TABLE A-21

SWFHYD PROGRAM INPUT DATA FILES

PECAN BAYOU WATERSHED MODEL:

```
* NOTE:  THIS MODEL WAS USED FOR THE MAINSTEM OF PECAN BAYOU.
*        AN ADJUSTED MODEL WAS DEVELOPED SPECIFICALLY FOR WILLIS CREEK.
*          IT HAS HIGHER INFILTRATION RATES FOR THE FREQUENT EVENTS.
BROWNWOOD - FEASIBILITY STUDY - MAY 2001
DATA
SCHEMATIC DIAGRAM DISPLAY = ON
POINT DISCHARGE DISPLAY = OFF
UHG DATA DISPLAY = OFF
MODIFIED UHG DISPLAY = ON
LOCAL PRINTOUT
3 3 3 3 3 3 3 3 3
COMBINE PRINTOUT
3 3 3 3 3 3 3 3 3
ROUTE PRINTOUT
3 3 3 3 3 3 3 3 3
* DATA
* 96 HOUR STORM
DATA
1 YEAR RAINFALL
1.0  1.3  1.58  1.75  2.15  2.54  2.875 3.4   3.7   4
2 YEAR RAINFALL
1.37 1.77 2.01  2.25  2.69  3.19  3.715 4.23  4.6   4.9
5 YEAR RAINFALL
1.72 2.29 2.77  3.045 3.655 4.37  5.085 5.5   5.9   6.4
10 YEAR RAINFALL
1.97 2.64 3.29  3.61  4.365 5.21  5.97  6.65  7.1   7.6
25 YEAR RAINFALL
2.32 3.15 3.845 4.275 5.185 6.11  7.09  8.05  8.6   9.1
50 YEAR RAINFALL
2.60 3.54 4.55  4.83  5.72  6.90  8.05  9.1   9.8  10.45
100 YEAR RAINFALL
2.87 3.93 4.875 5.40  6.53  7.81  9.10 10.45 11.0  11.5
500 YEAR RAINFALL
3.87 5.31 6.58  7.29  8.82 10.54 12.29 14.11 14.85 15.53
HYDRO-35 RAINFALL
0.994 1.77 1.842 3.93
SPF RAINFALL
14.15
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
DATA
UHG DATA
IMPERVIOUSNESS
PERCENT SAND
NO PRINTOUT
* CLYDE LAKE IS SCS FLOODWATER RETARDING SITE NO. 7 ON UPPER PECAN BAYOU.
* IT WAS THE LOCATION OF USGS GAGE "LAKE CLYDE NEAR CLYDE", GAGE NO. 08140600
* (JAN'70-SEP'85)
SUBAREA 1001 - NORTH PRONG PECAN BAYOU ABOVE CLYDE LAKE
37.33 9.20 2.82 15.9 0 2.7 100
* DISPLAY POINT
TITLED ROUTE
NORTH PRONG PECAN BAYOU BELOW CLYDE LAKE
0 0 5754 29 1
1840       0    58
1844       0   156
1845       0   195
1848       0   369
1852       0   745
1856       0  1329
1860       0  2191
1864       0  3369
1868       0  4855
```

```
1870.1      0  5754
1871       56  6167
1872      170  6647
1873      303  7149
1874      307  7672
1875      311  8212
1876      315  8768
1877      319  9342
1878      323  9940
1879.5    329 10885
1880      524 11213
1880.5   1060 11548
1881     1850 11891
1881.5   2850 12241
1882     4030 12599
1883     6800 13337
1884    10100 14103
1885    14000 14900
1886    18400 15728
1887    23200 16587
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO SOUTH PRONG PECAN BAYOU (14.21 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 570
* 2.2 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 4 SCS
* FLOODWATER RETARDING STRUCTURES (UPB#6,8,9,10).
* UPB STANDS FOR UPPER PECAN BAYOU.
DATA
1ST RIL & FAV
3.70 3.70 3.50 3.32 3.15 3.04 2.95 2.70 2.70
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
4.30 4.30 4.00 3.70 3.50 3.30 3.10 2.80 2.80
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1002 - NORTH PRONG SEGMENT ABOVE CONFLUENCE WITH SOUTH PRONG
72.38 24.19 13.20 11.9 0 0.2 100
TITLED COMBINE
NORTH PRONG PECAN BAYOU ABOVE SOUTH PRONG PECAN BAYOU
* DISPLAY POINT
* 2.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 6 SCS
* FLOODWATER RETARDING STRUCTURES (UPB#1,2,3,4A,4,11-A)
DATA
1ST RIL & FAV
4.00 4.00 3.80 3.62 3.45 3.34 3.25 3.00 3.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
4.60 4.60 4.30 4.00 3.80 3.60 3.40 3.10 3.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1003 - SOUTH PRONG PECAN BAYOU
79.44 21.36 12.42 20.6 0 0.2 100
* DISPLAY POINT
TITLED COMBINE
PECAN BAYOU BELOW CONFLUENCE OF NORTH AND SOUTH PRONGS
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO BURNT BRANCH (18.48 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 750
* 0.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 1 SCS
* FLOODWATER RETARDING STRUCTURE (UPB#12)
DATA
1ST RIL & FAV
2.00 2.00 1.80 1.62 1.45 1.34 1.25 1.00 1.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.60 2.60 2.30 2.00 1.80 1.60 1.40 1.10 1.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1004 - PECAN BAYOU SEGMENT ABOVE BURNT BRANCH
119.85 24.38 11.09 15.0 0 0 100
TITLED COMBINE
PECAN BAYOU ABOVE BURNT BRANCH
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
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TITLED ROUTE
DUMMY ROUTE TO BURKETT (11.59 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 470
* 1.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 8 SCS
* FLOODWATER RETARDING STRUCTURES (UPB#18A,19,20,21,22,23,24,25)
DATA
1ST RIL & FAV
3.00 3.00 2.80 2.62 2.45 2.34 2.25 2.00 2.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
3.60 3.60 3.30 3.00 2.80 2.60 2.40 2.10 2.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1005 - PECAN BAYOU SEGMENT ABOVE BURKETT
107.34 29.25 12.31 11.5 0 0.3 100
TITLED COMBINE
PECAN BAYOU AT BURKETT
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO TURKEY CREEK (8.76 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 350
* 1.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 13 SCS
* FLOODWATER RETARDING STRUCTURES (TC#1-A,1-B,2,3,4,5,6,7,8,9,10,11A,12)
DATA
1ST RIL & FAV
3.00 3.00 2.80 2.62 2.45 2.34 2.25 2.00 2.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
3.60 3.60 3.30 3.00 2.80 2.60 2.40 2.10 2.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1006 - PECAN BAYOU SEGMENT WHICH INCLUDES TURKEY CREEK
126.87 38.82 15.64 12.2 0 0.4 100
TITLED COMBINE
PECAN BAYOU BELOW TURKEY CREEK
* DISPLAY POINT
* USGS GAGE "PECAN BAYOU NEAR CROSS CUT", GAGE NO. 08140700 (APR'68-DEC'78) WAS
* LOCATED AT US HIGWAY 279, 1.19 MILES DOWNSTREAM OF TURKEY CREEK.
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO HOG CREEK (9.75 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 390
* 0.2 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 2 SCS
* FLOODWATER RETARDING STRUCTURES (UPB#26,34)
DATA
1ST RIL & FAV
1.70 1.70 1.50 1.32 1.15 1.04 0.95 0.70 0.70
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.30 2.30 2.00 1.70 1.50 1.30 1.10 0.80 0.80
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1007 - PECAN BAYOU SEGMENT ABOVE HOG CREEK (ACTUALLY DAMSITE A1)
110.77 28.05 11.97 13.2 0 0.1 100
TITLED COMBINE
PECAN BAYOU ABOVE HOG CREEK (ACTUALLY AT DAMSITE A1)
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO DAMSITE Z1 (2.94 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 120
* 0.4 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 4 SCS
* FLOODWATER RETARDING STRUCTURES (UPB#30,31,32,33)
DATA
1ST RIL & FAV
1.90 1.90 1.70 1.52 1.35 1.24 1.15 0.90 0.90
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.50 2.50 2.20 1.90 1.70 1.50 1.30 1.00 1.00
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
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SUBAREA 1008 - PECAN BAYOU SEGMENT WHICH INCLUDES HOG CREEK
86.73 17.74 11.01 12.6 0 0.2 100
TITLED COMBINE
PECAN BAYOU BELOW HOG CREEK (ABOVE LAKE BROWNWOOD)
* DISPLAY POINT
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1009 - PECAN BAYOU SEGMENT ADJACENT TO LAKE BROWNWOOD
38.92 8.22 5.64 27.7 0 12.4 100
TITLED COMBINE
PECAN BAYOU' INFLOWS TO LAKE BROWNWOOD
* DISPLAY POINT
* 1.9 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 15 SCS
* FLOODWATER RETARDING STRUCTURES (JNC#9,10,11,12,12A,12C,12E-1,12F,15,16,
* 17,17B-1,19,20,21).  JNC STANDS FOR JIM NED CREEK.
DATA
1ST RIL & FAV
3.40 3.40 3.20 3.02 2.85 2.74 2.65 2.40 2.40
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
4.00 4.00 3.70 3.40 3.20 3.00 2.80 2.50 2.50
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1010 - JIM NED CREEK ABOVE LAKE COLEMAN
305.06 35.24 12.04 9.4 0 1.6 100
* DISPLAY POINT
TITLED ROUTE
JIM NED CREEK BELOW LAKE COLEMAN
0 0 38846 24 1
1650         0     0
1670         0   464
1680         0  1926
1690         0  6156
1695         0  9652
1700         0 14048
1705         0 19473
1710         0 26177
1715         0 34287
1717.5       0 38846
1718        70 39789
1719       380 41730
1720       810 43731
1721      1340 45789
1722      1770 47899
1724      1800 52278
1726      1830 56866
1728      8850 61658
1730     30900 66664
1732     62900 71878
1734    105000 77285
1736    151000 82889
1738    200000 88698
1740    252000 94716
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO US HIGHWAY 283 GAGESITE (7.46 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 301
* 3.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 2 SCS
* FLOODWATER RETARDING STRUCTURES (JNC#22,23)
DATA
1ST RIL & FAV
5.00 5.00 4.80 4.62 4.45 4.34 4.25 4.00 4.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
5.60 5.60 5.30 5.00 4.80 4.60 4.40 4.10 4.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1011 - JIM NED CREEK SEGMENT ABOVE US HIGHWAY 283 GAGESITE
34.91 14.14 5.73 34.3 0 0.2 100
TITLED COMBINE
JIM NED CREEK AT US HIGHWAY 283 GAGESITE
* DISPLAY POINT
* THIS WAS THE LOCATION OF USGS GAGE "JIM NED CREEK NEAR COLEMAN, GAGE NO.
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* 08140800 (OCT'61-SEP'64 AND MAR'65-SEP'80)
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO HORDS CREEK (18.46 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 750
* 2.0 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 8 SCS
* FLOODWATER RETARDING STRUCTURES (JNC#5,6,7,8,24,25,25A,25B)
* **** DON'T FORGET TO GET DATA FOR SITE NO. 4 FROM SCS OFFICE*****
* **** THIS WILL MAKE 9 TOTAL SITES, BUT MAY NOT AFFECT THE 2.0 INCH *****
DATA
1ST RIL & FAV
3.50 3.50 3.30 3.12 2.95 2.84 2.75 2.50 2.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
4.10 4.10 3.80 3.50 3.30 3.10 2.90 2.60 2.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1012 - JIM NED CREEK SEGMENT ABOVE HORDS CREEK
109.82 24.19 14.30 10.6 0 0.4 100
* **** DON'T FORGET TO GET DATA FOR SITE NO. 4 FROM SCS OFFICE*****
* **** THIS WILL PROBABLY INCREASE THE IMPERVIOUSNESS VALUE   *****
TITLED COMBINE
JIM NED CREEK ABOVE HORDS CREEK
* DISPLAY POINT
* 0.5 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 1 SCS
* FLOODWATER RETARDING STRUCTURE (JNC#37)
DATA
1ST RIL & FAV
2.00 2.00 1.80 1.62 1.45 1.34 1.25 1.00 1.00
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.60 2.60 2.30 2.00 1.80 1.60 1.40 1.10 1.10
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1013 - HORDS CREEK ABOVE HORDS CREEK LAKE
49.06 9.79 3.18 24.4 0 1.7 100
TITLED ROUTE
HORDS CREEK BELOW HORDS CREEK LAKE
0 0 24500 24 1
1860     0   100
1870     0   500
1880     0  1700
1890     0  4000
1895     0  5700
1900     0  8000
1905     0 11000
1910     0 14400
1915     0 19000
1920     0 24500
1921   800 25900
1922  1700 27200
1923  3900 28500
1924  6500 30100
1925 10000 31700
1926 14000 33400
1927 18500 35300
1928 24000 37000
1929 29500 38800
1930 40700 35500
1931 42000 42700
1932 49000 44800
1933 56400 47000
1934 64400 49400
* DISPLAY POINT
* THIS IS THE LOCATION OF USGS GAGE "HORDS CREEK LAKE NEAR VALERA", GAGE NO.
* 08141000 (APR'48-PRESENT).  ANOTHER USGS GAGE, "HORDS CREEK NEAR VALERA" IS
* LOCATED AT FM 503, 1.17 MILES DOWNSTREAM (APR'47-PRESENT).  ANOTHER USGS GAGE,
* "HORDS CREEK ABOVE COLEMAN" WAS LOCATED ABOUT 3.8 MILES WEST OF COLEMAN IN
* THE 1940'S.  ANOTHER USGS GAGE "HORDS CREEK AT COLEMAN", GAGE NO.08142000, IS
* IN COLEMAN, JUST BELOW US HIGHWAYS 84 AND 283 (OCT'40-PRESENT).
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO MOUTH (29.18 RIVER MILES)
0 0 0 2 1
1    0    0
2 1000 1200
* 1.0 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
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* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 7 SCS
* FLOODWATER RETARDING STRUCTURES (JNC#31,32,33,34A,35,36,37)
DATA
1ST RIL & FAV
2.50 2.50 2.30 2.12 1.95 1.84 1.75 1.50 1.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
3.10 3.10 2.80 2.50 2.30 2.10 1.90 1.60 1.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1014 - HORDS CREEK SEGMENT ABOVE MOUTH
98.47 35.40 19.76 15.5 0 0.2 100
TITLED COMBINE
HORDS CREEK ABOVE JIM NED CREEK
* DISPLAY POINT
TITLED COMBINE
JIM NED CREEK BELOW HORDS CREEK
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=3
TITLED ROUTE
DUMMY ROUTE TO KEELER KNOB (16.49 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 670
* 1.2 INCHES OF INITIAL LOSSES HAVE BEEN ADDED IN THE FOLLOWING SUBAREA TO
* ACCOUNT FOR VOLUMETRIC DETENTION BY THE OTHERWISE UNACCOUNTED FOR 5 SCS
* FLOODWATER RETARDING STRUCTURES (JNC#2,3,26A,27,28)
DATA
1ST RIL & FAV
2.70 2.70 2.50 2.32 2.15 2.04 1.95 1.70 1.70
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
3.30 3.30 3.00 2.70 2.50 2.30 2.20 1.80 1.80
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1015 - JIM NED CREEK SEGMENT ABOVE KEELER KNOB
118.85 21.00 9.81 12.7 0 0.3 100
TITLED COMBINE
JIM NED CREEK AT KEELER KNOB (ABOVE LAKE BROWNWOOD)
* DISPLAY POINT
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 1016 - JIM NED CREEK SEGMENT ADJACENT TO LAKE BROWNWOOD
70.00 8.96 5.22 22.5 0 7.9 100
TITLED COMBINE
JIM NED CREEK' INFLOWS TO LAKE BROWNWOOD
* DISPLAY POINT
TITLED COMBINE
TOTAL INFLOWS TO LAKE BROWNWOOD
* DISPLAY POINT
TITLED ROUTE
PECAN BAYOU BELOW LAKE BROWNWOOD
0 0 118900 40 1
* 1383      0       0
* 1384      0      30
* 1385      0     110
* 1386      0     240
* 1387      0     440
* 1388      0     720
* 1389      0    1110
* 1390      0    1630
* 1391      0    2290
* 1392      0    3080
* 1393      0    4000
* 1394      0    5070
* 1395      0    6265
* 1396      0    7590
* 1397      0    9030
* 1398      0   10600
* 1399      0   12270
* 1400      0   14020
* 1401      0   15920
* 1402      0   18050
* 1403      0   20370
* 1404      0   22850
* 1405      0   25500
* 1406      0   28300
* 1407      0   31270
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* 1408       0   34400
* 1409       0   37660
* 1410       0   41020
* 1411       0   44530
* 1412       0   48280
* 1413       0   52255
* 1414       0   56470
* 1415       0   60910
* 1416       0   65590
* 1417       0   70510
* 1418       0   75660
* 1419       0   81045
1420       0   86670
1421       0   92510
1422       0   98550
1423       0  104900
1424       0  111700
1425       0  118900
1426    1000  126700
1427    3500  134900
1428    6000  143400
1429    9000  152400
1430   12500  161700
1431   16500  171400
1432   20500  181600
1433   25500  192300
1434   31000  203400
1435   36500  215000
1436   42500  227000
1437   48000  239600
1438   55500  252600
1439   61500  266100
1440   70000  280000
1441   78500  294500
1442   85500  309400
1443   95500  324900
1444  103500  340900
1445  114000  357400
1446  123000  374400
1447  131500  392000
1448  145000  410200
1449  154000  428900
1450  161000  448200
1451  173000  468200
1452  183000  489100
1453  193000  511000
1454  203000  533700
1455  216000  557400
1456  224000  581900
1457  234000  607100
1458  254000  633000
1459  265000  659600
* 1460 279000  686900
* 1461 289000  715000
* 1462 312000  743700
* 1463 324000  773200
* 1464 349000  803300
* 1465 358000  834200
* 1466 391000  865800
* 1467 405000  898100
* 1468 420000  931100
* 1469 434000  964800
* 1470 449000  999300
* 1471 464000 1034500
* 1472 479000 1070500
* 1473 495000 1107200
* 1474 510000 1144800
* 1475 526000 1183300
* 1476 542000 1222500
* 1477 558000 1262400
* 1478 574000 1303200
* 1479 590000 1344700
* 1480 607000 1387700
* DISPLAY POINT
* THIS IS THE LOCATION OF USGS GAGE "LAKE BROWNWOOD NEAR BROWNWOOD", GAGE NO.
* 08143000 (JUL'33-MAY'41 AND NOV'44-SEP'86).
TITLED ROUTE
ROUTE TO ELM CREEK
0 0 0 10 1
1      0    0
2   1275  262
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3   4220  645
4  11500 1385
5  18200 1905
6  25900 2441
7  37100 3223
8  46300 3888
9  56000 4830
10 69700 6267
SUBAREA 40 - PECAN BAYOU LOCAL AREA ABOVE ELM CREEK
6.34 8.05 4.4 32 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE ELM CREEK
* DISPLAY POINT
* THE "BL" NOTATION FOR THE FOLLOWING SERIES OF SCS FLOODWATER RETARDING SITES
* STANDS FOR BROWNWOOD LATERALS.  THE "BC" NOTATION FOR THOSE NEARER THE END OF
* THE MODEL STANDS FOR BLANKET CREEK, WHICH IS A MAJOR LEFT BANK TRIB OF P.B.
SUBAREA 41 - ELM CREEK HEADWATERS ABOVE SCS SITE BL#6
1.29 1.87 1..1 110 0 1 100
TITLED ROUTE
ELM CREEK BELOW SCS SITE BL#6
0 0 46 15 1
1672      0   4
1676      0  16
1680      0  42
1680.4    0  46
1684     11  88
1688     12 156
1692     13 254
1694.5   14 334
1695     46 352
1696    264 389
1697    615 430
1698   1090 473
1699   1680 520
1699.3 1870 534
1700   2880 569
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS BL#10A TRIBUTARY (5.29 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 130
SUBAREA 42 - ELM CREEK LOCAL AREA ABOVE SCS BL#10A TRIBUTARY
4.43 6.27 3.3 35 0 0 100
TITLED COMBINE
ELM CREEK ABOVE SCS BL#10A TRIBUTARY
SUBAREA 43 - SCS BL#10A TRIBUTARY HEADWATERS ABOVE DAMSITE
3.17 2.82 1.7 60 0 1 100
***** THE FOLLOWING DATA IS NOT CORRECT FOR THIS PARTICULAR DAM ******
***** WE ARE AWAITING PROPER DATA FROM SCS OFFICE, TO BE THEN INPUT ***
TITLED ROUTE
SCS BL#10A TRIBUTARY BELOW DAMSITE
0 0 46 15 1
1672      0   4
1676      0  16
1680      0  42
1680.4    0  46
1684     11  88
1688     12 156
1692     13 254
1694.5   14 334
1695     46 352
1696    264 389
1697    615 430
1698   1090 473
1699   1680 520
1699.3 1870 534
1700   2880 569
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.67 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 40
SUBAREA 44 - SCS BL#10A TRIBUTARY LOCAL AREA ABOVE MOUTH
1.14 2.26 1.2 43 0 0 100
TITLED COMBINE
SCS BL#10A TRIBUTARY ABOVE ELM CREEK
TITLED COMBINE
ELM CREEK BELOW SCS BL#10A TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
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TITLED ROUTE
DUMMY ROUTE TO MOUTH (8.42 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 200
SUBAREA 45 - ELM CREEK LOCAL AREA ABOVE MOUTH
7.11 8.55 4.4 19 0 0 100
TITLED COMBINE
ELM CREEK ABOVE PECAN BAYOU
TITLED COMBINE
PECAN BAYOU BELOW ELM CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO SALT CREEK
0 0 0 10 1
1      0   0
2   1275  11
3   4220  27
4  11500  58
5  18200  79
6  25900 102
7  37100 134
8  46300 162
9  56000 201
10 69700 261
SUBAREA 63 - PECAN BAYOU LOCAL AREA ABOVE SALT CREEK
0.02 0.27 0.12 160 0 10 100
TITLED COMBINE
PECAN BAYOU ABOVE SALT CREEK
* DISPLAY POINT
SUBAREA 46 - SALT CREEK HEADWATERS ABOVE SCS SITE BL#13
3.75 2.59 1.2 93 0 1 100
TITLED ROUTE
SALT CREEK BELOW SCS SITE BL#13
0 0 117 20 1
1572      0    2
1576      0    8
1580      0   22
1584      0   48
1588      0   88
1590.1    0  117
1592     28  152
1596     31  250
1600     35  390
1604     37  578
1608     40  816
1610.1   41  965
1611    327 1035
1612   1080 1118
1613   2170 1205
1614   3565 1296
1615   5140 1390
1615.2 5540 1410
1616   7550 1487
1616.5 9680 1537
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS BL#15 TRIBUTARY (1.92 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 47
SUBAREA 47 - SALT CREEK LOCAL AREA ABOVE SCS BL#15 TRIBUTARY
1.72 2.73 1.4 68 0 0 100
TITLED COMBINE
SALT CREEK ABOVE SCS BL#15 TRIBUTARY
SUBAREA 48 - SCS BL#15 TRIBUTARY HEADWATERS ABOVE DAMSITE
1.49 1.46 0.7 120 0 1 100
TITLED ROUTE
SCS BL#15 TRIBUTARY BELOW DAMSITE
0 0 36 13 1
1540      0  10
1544      0  36
1548     55  84
1552     62 160
1556     68 276
1557     69 312
1558    192 350
1559    493 391
1560    909 435
1561   1440 481
1562   2080 531
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1562.2 2240 541
1563   3120 583
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.70 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 17
SUBAREA 49 - SCS BL#15 TRIBUTARY LOCAL AREA ABOVE MOUTH
0.29 0.88 0.4 130 0 0 100
TITLED COMBINE
SCS BL#15 TRIBUTARY ABOVE SALT CREEK
TITLED COMBINE
SALT CREEK BELOW SCS BL#15 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS BL#14 TRIBUTARY (0.92 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
SUBAREA 50 - SALT CREEK LOCAL AREA ABOVE SCS BL#14 TRIBUTARY
0.34 1.03 0.5 65 0 0 100
TITLED COMBINE
SALT CREEK ABOVE SCS BL#14 TRIBUTARY
SUBAREA 51 - SCS BL#14 TRIBUTARY HEADWATERS ABOVE DAMSITE
1.04 2.55 1.5 82 0 2 100
TITLED ROUTE
SCS BL#14 TRIBUTARY BELOW DAMSITE
0 0 35 12 1
1536      0  10
1538      0  35
1540      8  62
1544      9 152
1547.2   11 258
1548     60 288
1549    229 328
1550    491 371
1551    837 416
1551.8 1170 454
1552   1270 464
1552.8 2670 504
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.29 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 31
SUBAREA 52 - SCS BL#14 TRIBUTARY LOCAL AREA ABOVE MOUTH
2.36 4.18 2.4 60 0 0 100
TITLED COMBINE
SCS BL#14 TRIBUTARY ABOVE MOUTH
TITLED COMBINE
SALT CREEK BELOW SCS BL#14 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO GAP CREEK (0.59 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 14
SUBAREA 53 - SALT CREEK LOCAL AREA ABOVE GAP CREEK
0.47 1.56 0.8 90 0 0 100
TITLED COMBINE
SALT CREEK ABOVE GAP CREEK
SUBAREA 54 - GAP CREEK ABOVE SALT CREEK
12.49 11.06 7.4 37 0 0 100
TITLED COMBINE
SALT CREEK BELOW GAP CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS BL#16A TRIBUTARY (0.84 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 20
SUBAREA 55 - SALT CREEK LOCAL AREA ABOVE SCS BL#16A TRIBUTARY
1.45 4.25 2.8 52 0 0 100
TITLED COMBINE
SALT CREEK ABOVE SCS BL#16A TRIBUTARY
SUBAREA 56 - SCS BL#16A TRIBUTARY HEADWATERS ABOVE DAMSITE
3.98 4.19 2.2 54 0 1 100
TITLED ROUTE
SCS BL#16A TRIBUTARY BELOW DAMSITE
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0 0 74 13 1
1472    0   18
1476    0   74
1480   25  178
1484   30  320
1488   34  534
1492   38  850
1493  207  945
1494  605 1046
1495 1180 1155
1496 1890 1271
1497 2750 1395
1498 3770 1527
1499 7260 1667
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.22 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 5
TITLED COMBINE
SALT CREEK BELOW SCS BL#16A TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO BERRY BRANCH (2.34 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 57
SUBAREA 57 - SALT CREEK LOCAL AREA ABOVE BERRY BRANCH
2.15 3.50 2.3 38 0 0 100
TITLED COMBINE
SALT CREEK ABOVE BERRY BRANCH
SUBAREA 58 - BERRY BRANCH HEADWATERS ABOVE SCS SITE BL#11
0.98 2.49 1.2 47 0 1 100
TITLED ROUTE
BERRY BRANCH BELOW SCS SITE BL#11
0 0 26 14 1
1552       0   4
1556       0  24
1556.2     0  26
1560       9  72
1564      11 148
1567.2    12 233
1568      61 258
1569     233 293
1570     495 330
1571     843 371
1571.7  1140 402
1572    1350 416
1572.5  2530 439
1576   39900 619
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (4.59 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 110
SUBAREA 59 - BERRY BRANCH LOCAL AREA ABOVE MOUTH
2.66 4.99 2.7 28 0 0 100
TITLED COMBINE
BERRY BRANCH ABOVE SALT CREEK
TITLED COMBINE
SALT CREEK BELOW BERRY BRANCH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (5.75 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 140
SUBAREA 60 - SALT CREEK LOCAL AREA ABOVE RED HOLE CREEK
3.35 6.45 4.0 24 0 1 100
TITLED COMBINE
SALT CREEK ABOVE RED HOLE CREEK
SUBAREA 61 - RED HOLE CREEK ABOVE SALT CREEK
6.60 9.22 6.1 24 0 0 100
TITLED COMBINE
SALT CREEK BELOW RED HOLE CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.14 RIVER MILES)
0 0 0 2 1
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1    0 0
2 1000 3
SUBAREA 62 - SALT CREEK LOCAL AREA ABOVE MOUTH
0.01 0.14 0.07 240 0 0 100
TITLED COMBINE
SALT CREEK ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW SALT CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO NEXT RIGHT BANK TRIBUTARY
0 0 0 10 1
1      0    0
2   1275  117
3   4220  253
4  11500  477
5  18200  797
6  25900 1335
7  37100 1836
8  46300 2173
9  56000 2497
10 69700 2935
SUBAREA 64 - PECAN BAYOU LOCAL AREA LOCATED WEST OF BROWNWOOD MUNICIPAL AIRPORT
1.08 1.95 1.2 19 0 4 100
TITLED COMBINE
PECAN BAYOU ABOVE RIGHT BANK TRIBUTARY
* DISPLAY POINT
SUBAREA 65 - RIGHT BANK TRIBUTARY ABOVE MOUTH
4.43 2.81 1.5 70 0 1 100
TITLED COMBINE
PECAN BAYOU BELOW RIGHT BANK TRIBUTARY
* DISPLAY POINT
TITLED ROUTE
ROUTE TO SCS BL#17 TRIBUTARY
0 0 0 10 1
1      0    0
2   1275  254
3   4220  544
4  11500 1019
5  18200 1412
6  25900 2040
7  37100 3315
8  46300 4147
9  56000 4927
10 69700 5896
SUBAREA 66 - PECAN BAYOU LOCAL AREA ABOVE SCS BL#17 TRIBUTARY
0.89 2.45 1.3 16 0 3 100
TITLED COMBINE
PECAN BAYOU ABOVE SCS BL#17 TRIBUTARY
* DISPLAY POINT
SUBAREA 67 - SCS BL#17 TRIBUTARY HEADWATERS ABOVE DAMSITE
1.86 1.95 1.0 60 0 1 100
TITLED ROUTE
SCS BL#17 TRIBUTARY BELOW DAMSITE
0 0 41 17 1
1424        0   10
1428        0   40
1428.1      0   41
1432       49   98
1436       57  194
1440       64  348
1441.5     66  423
1442      111  450
1443      418  507
1444      897  569
1445     1540  635
1446     2350  706
1446.1   2440  713
1446.8   3310  766
1447     4000  781
1448    10000  861
1452    55400 1239
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (6.28 RIVER MILES)
0 0 0 2 1
1    0    0
2 1000 150
SUBAREA 68 - SCS BL#17 TRIBUTARY LOCAL AREA ABOVE MOUTH
7.05 7.37 4.3 16 0 2 100
TITLED COMBINE
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SCS BL#17 TRIBUTARY ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW SCS BL#17 TRIBUTARY
* DISPLAY POINT
TITLED ROUTE
ROUTE TO US HIGHWAYS 67/84/377
0 0 0 10 1
1      0    0
2   1275  349
3   4220  583
4  11500 1157
5  18200 1963
6  25900 3117
7  37100 4887
8  46300 6111
9  56000 7268
10 69700 8758
SUBAREA 69 - PECAN BAYOU LOCAL AREA ABOVE US HIGHWAYS 67/84/377
4.21 5.84 3.3 26 5 3 100
TITLED COMBINE
PECAN BAYOU AT US HIGHWAYS 67/84/377
DISPLAY POINT
* NOTE THAT THIS LAST POINT DOES NOT INCLUDE LOCALIZED RUNOFF FROM THE ADAMS
* BRANCH SLOUGH, WHICH MAY AFFECT THE COMPARISON WITH USGS GAGE DATA AT THE
* NEARBY STATION "PECAN BAYOU AT BROWNWOOD", GAGE NO. 08143500 (MAY'17-JUN'18,
* OCT'23-SEP'83).
TITLED ROUTE
ROUTE TO EARLY DRAINAGE SWALE (OVERLAND FLOWPATH)
0 0 0 10 1
1      0    0
2   1275  128
3   4220  287
4  11500  631
5  18200 1103
6  25900 2026
7  37100 3213
8  46300 4119
9  56000 5074
10 69700 6565
SUBAREA 70 - PECAN BAYOU LOCAL AREA ABOVE EARLY DRAINAGE SWALE (OVERLAND PATH)
2.52 2.83 1.4 46 10 6 100
TITLED COMBINE
PECAN BAYOU ABOVE EARLY DRAINAGE SWALE (OVERLAND FLOWPATH)
* DISPLAY POINT
SUBAREA 71 - EARLY DRAINAGE SWALE (OVERLAND FLOWPATH)
2.19 3.95 2.1 34 10 6 100
TITLED COMBINE
PECAN BAYOU BELOW EARLY DRAINAGE SWALE (OVERLAND FLOWPATH)
* DISPLAY POINT
TITLED ROUTE
ROUTE TO ADAMS BRANCH
0 0 0 10 1
1      0    0
2   1275   56
3   4220  137
4  11500  384
5  18200  588
6  25900  929
7  37100 1514
8  46300 1994
9  56000 2494
10 69700 3236
SUBAREA 72 - PECAN BAYOU LOCAL AREA ABOVE ADAMS BRANCH
0.25 1.13 0.7 39 0 4 100
TITLED COMBINE
PECAN BAYOU ABOVE ADAMS BRANCH
* DISPLAY POINT
****  WE STILL NEED DATA ON THE TWO SCS LAKES ON THE ADAMS BRANCH WATERSHED****
****  BEFORE WE CAN ASSIGN THE PARTICULAR DRAINAGE AREA LOCATIONS.*************
SUBAREA 27 - ADAMS BRANCH HEADWATERS ABOVE SCS BL#??? DAMSITE
1.38 1.56 0.9 120 0 2 100
* TITLED ROUTE
* ADAMS BRANCH BELOW SCS BL#?? DAMSITE
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (2.62 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000  64
SUBAREA 28 - ADAMS BRANCH LOCAL AREA ABOVE SCS BL#?? TRIBUTARY
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3.58 5.14 3.0 37 0 0 100
TITLED COMBINE
ADAMS BRANCH ABOVE SCS BL#?? TRIBUTARY
SUBAREA 29 - SCS BL#?? TRIBUTARY ABOVE DAMSITE
5.23 1.36 0.6 130 0 1 100
* TITLED ROUTE
* SCS BL#?? TRIBUTARY BELOW DAMSITE
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.13 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 3
TITLED COMBINE
ADAMS BRANCH BELOW SCS BL#??? TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO BLUFF VIEW ADDITION TRIBUTARY (1.59 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 39
SUBAREA 30 - ADAMS BRANCH LOCAL AREA ABOVE BLUFF VIEW ADDITION TRIBUTARY
1.71 2.98 1.5 28 10 10 100
TITLED COMBINE
ADAMS BRANCH ABOVE BLUFF VIEW ADDITION TRIBUTARY
SUBAREA 31 - BLUFF VIEW ADDITION TRIBUTARY ABOVE MOUTH
0.79 1.34 0.8 50 10 5 100
TITLED COMBINE
ADAMS BRANCH BELOW BLUFF VIEW ADDITION TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO TOM WILLIAMS CREEK (0.83 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 20
SUBAREA 32 - ADAMS BRANCH LOCAL AREA ABOVE TOM WILLIAMS CREEK
0.32 0.93 0.5 46 50 25 100
TITLED COMBINE
ADAMS BRANCH ABOVE TOM WILLIAMS CREEK
SUBAREA 23 - TOM WILLIAMS CREEK HEADWATERS ABOVE SCS SITE BL#???
2.93 1.97 1.1 48 0 1 100
* TITLED ROUTE
* TOM WILLIAMS CREEK BELOW SCS SITE BL#???
*
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO ADAMS BRANCH (2.81 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 68
SUBAREA 24 - TOM WILLIAMS CREEK LOCAL AREA ABOVE ADAMS BRANCH
1.92 4.50 1.6 51 10 5 100
TITLED COMBINE
TOM WILLIAMS CREEK ABOVE ADAMS BRANCH
TITLED COMBINE
ADAMS BRANCH BELOW TOM WILLIAMS CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO ADAMS BRANCH SLOUGH (0.93 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 23
SUBAREA 33 - ADAMS BRANCH LOCAL AREA ABOVE ADAMS BRANCH SLOUGH
0.51 1.42 0.7 23 80 40 100
TITLED COMBINE
ADAMS BRANCH ABOVE ADAMS BRANCH SLOUGH
SUBAREA 25 - ADAMS BRANCH SLOUGH HEADWATERS ABOVE SCS SITE BL#8
2.82 2.32 0.8 79 0 1 100
TITLED ROUTE
ADAMS BRANCH SLOUGH BELOW SCS SITE #8
0 0 69 18 1
1372      0   13
1376      0   33
1380      0   69
1384     21  117
1388     24  175
1392     27  247
1396     29  339
1400     31  457
1404     33  635
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1408     35  921
1409    148 1014
1410    436 1119
1411    831 1236
1412   1340 1367
1413   1970 1510
1413.9 2640 1651
1415   4090 1840
1416   7970 2028
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (7.26 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 180
SUBAREA 26 - ADAMS BRANCH SLOUGH LOCAL AREA ABOVE MOUTH
11.45 8.34 4.5 6 5 3 100
TITLED COMBINE
ADAMS BRANCH SLOUGH ABOVE ADAMS BRANCH
TITLED COMBINE
ADAMS BRANCH BELOW ADAMS BRANCH SLOUGH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (2.96 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 72
SUBAREA 34 - ADAMS BRANCH LOCAL AREA ABOVE MOUTH
0.95 3.16 1.7 6 20 10 100
TITLED COMBINE
ADAMS BRANCH ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW ADAMS BRANCH
* DISPLAY POINT
TITLED ROUTE
ROUTE TO DELAWARE CREEK
0 0 0 10 1
1      0    0
2   1275   28
3   4220   68
4  11500  189
5  18200  290
6  25900  458
7  37100  745
8  46300  982
9  56000 1228
10 69700 1594
SUBAREA 73 - PECAN BAYOU LOCAL AREA ABOVE DELAWARE CREEK
0.12 0.62 0.3 77 0 4 100
TITLED COMBINE
PECAN BAYOU ABOVE DELAWARE CREEK
* DISPLAY POINT
SUBAREA 74 - DELAWARE CREEK ABOVE MOUTH
13.91 12.08 7.0 23 2 1 100
TITLED COMBINE
PECAN BAYOU BELOW DELAWARE CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO WILLIS CREEK
0 0 0 10 1
1      0    0
2   1275   80
3   4220  349
4  11500 1363
5  18200 1878
6  25900 2224
7  37100 2642
8  46300 2943
9  56000 3241
10 69700 3679
SUBAREA 75 - PECAN BAYOU LOCAL AREA ABOVE WILLIS CREEK
0.92 1.86 1.1 53 0 2 100
TITLED COMBINE
PECAN BAYOU ABOVE WILLIS CREEK
* DISPLAY POINT
SUBAREA 1 - WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#3
8.53 4.66 1.8 32 0 1 100
DATA
1ST RIL & FAV
100  100  100  100  100  100  100  100  100
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
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2ND RIL & FAV
100  100  100  100  100  100  100  100  100
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 2 - QUARRY (NOTE INFINITE RAINFALL LOSSES)
0.67 2 1 1 0 0 100
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
TITLED COMBINE
WILLIS CREEK ABOVE SCS SITE BL#3
TITLED ROUTE
WILLIS CREEK BELOW SCS SITE BL#3
0 0 400 26 1
1420       0  152
1422.1     0  198
1424       0  244
1428       0  364
1429       0  400
1432     104  520
1436     110  718
1400     116  956
1444     122 1230
1448     128 1546
1452     133 1918
1456     138 2388
1460     143 3012
1464     148 3874
1465     586 4136
1466    1200 4418
1467    3090 4718
1468    4910 5038
1469    7160 5378
1470    9460 5740
1471   12200 6125
1472   15000 6532
1473   18300 6953
1474   21700 7380
1474.4 23100 7553
1476.7 35500 8565
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE 2400 FEET, TO END OF HEC-2 MODEL (0.45 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 11
TITLED ROUTE
ROUTE TO US HIGHWAY 377
0 0 0 13 1
1      0  0
2    500  5
3   1000  7
4   1500 10
5   2500 15
6   3500 21
7   4500 28
8   5500 35
9   7000 46
10  8000 52
11 10000 65
12 12000 80
13 15000 98
SUBAREA 3 - WILLIS CREEK LOCAL AREA ABOVE US HIGHWAY 377
0.70 1.38 0.7 32 20 10 100
TITLED COMBINE
WILLIS CREEK AT US HIGHWAY 377
TITLED ROUTE
ROUTE TO RAILROAD SPUR
0 0 0 13 1
1      0   0
2    500  10
3   1000  15
4   1500  20
5   2500  29
6   3500  40
7   4500  56
8   5500  69
9   7000  89
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10  8000 103
11 10000 131
12 12000 145
13 15000 172
SUBAREA 4 - WILLIS CREEK LOCAL AREA ABOVE RAILROAD SPUR
0.49 0.75 0.4 130 30 15 100
TITLED COMBINE
WILLIS CREEK AT RAILROAD SPUR
TITLED ROUTE
ROUTE TO CUSTER ROAD
0 0 0 13 1
1      0   0
2    500  30
3   1000  59
4   1500  96
5   2500 159
6   3500 257
7   4500 369
8   5500 385
9   7000 420
10  8000 448
11 10000 500
12 12000 565
13 15000 663
SUBAREA 5 - WILLIS CREEK LOCAL AREA ABOVE CUSTER ROAD
0.93 1.74 0.8 31 40 20 100
TITLED COMBINE
WILLIS CREEK AT CUSTER ROAD
TITLED ROUTE
ROUTE TO SOUTH WILLIS CREEK
0 0 0 13 1
1      0   0
2    500  43
3   1000  71
4   1500 104
5   2500 174
6   3500 245
7   4500 327
8   5500 394
9   7000 491
10  8000 552
11 10000 677
12 12000 800
13 15000 951
SUBAREA 6 - WILLIS CREEK LOCAL AREA ABOVE SOUTH WILLIS CREEK
1.23 2.32 1.2 26 70 35 100
TITLED COMBINE
WILLIS CREEK ABOVE SOUTH WILLIS CREEK
SUBAREA 7 - SOUTH WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#4A
0.84 1.27 0.6 97 0 2 100
TITLED ROUTE
SOUTH WILLIS CREEK BELOW SCS SITE BL#4A
0 0 38 18 1
1448       0   6
1451       0  18
1452       0  24
1453.8     0  38
1456      81  62
1460      93 134
1464     105 248
1465.5   109 299
1466     154 316
1467     450 352
1468     932 389
1469    1560 428
1470    2330 469
1471    3210 513
1472    4270 559
1472.3  4590 574
1473.3  6490 623
1476   29100 764
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO COUNTRY CLUB TRIBUTARY (1.56 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 38
SUBAREA 8 - SOUTH WILLIS CREEK LOCAL AREA ABOVE COUNTRY CLUB TRIBUTARY
1.81 2.17 1.0 57 2 1 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE COUNTRY CLUB TRIBUTARY
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SUBAREA 9 - COUNTRY CLUB TRIBUTARY HEADWATERS ABOVE SCS SITE BL#4B
1.14 1.07 0.4 130 0 2 100
TITLED ROUTE
COUNTRY CLUB TRIBUTARY BELOW SCS SITE BL#4B
0 0 47 15 1
1452       0    4
1454       0   15
1456.8     0   47
1460      87  114
1464      99  242
1468     110  428
1469     330  486
1470     862  548
1471    1620  616
1472    2560  689
1473    3690  767
1474    4940  851
1474.5  5690  896
1475.6  8440  999
1476   10700 1038
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO COUNTRY CLUB LAKE (0.90 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
SUBAREA 10 - COUNTRY CLUB TRIBUTARY LOCAL AREA ABOVE COUNTRY CLUB LAKE DAM
0.79 0.82 0.3 220 2 6 100
TITLED COMBINE
COUNTRY CLUB TRIBUTARY AT COUNTRY CLUB LAKE DAM
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.91 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
SUBAREA 11 - COUNTRY CLUB TRIBUTARY LOCAL AREA ABOVE MOUTH
0.78 1.62 0.9 72 2 1 100
TITLED COMBINE
COUNTRY CLUB TRIBUTARY ABOVE SOUTH WILLIS CREEK
TITLED COMBINE
SOUTH WILLIS CREEK BELOW COUNTRY CLUB TRIBUTARY (AT STATE HWY. 45, MILAM DRIVE)
* DISPLAY POINT
TITLED ROUTE
ROUTE TO MORRIS SHEPPARD DRIVE
0 0 0 10 1
1     0   0
2   500   8
3  1000  15
4  1500  23
5  2000  45
6  3000  85
7  4500 114
8  6000 148
9  7500 180
10 9000 217
SUBAREA 12 - SOUTH WILLIS CREEK LOCAL AREA ABOVE MORRIS SHEPPARD DRIVE
0.75 1.30 0.6 62 10 5 100
TITLED COMBINE
SOUTH WILLIS CREEK AT MORRIS SHEPPARD DRIVE
* DISPLAY POINT
TITLED ROUTE
ROUTE TO KREUGER HILL TRIBUTARY
0 0 0 10 1
1     0   0
2   500  15
3  1000  27
4  1500  40
5  2000  54
6  3000  82
7  4500 116
8  6000 145
9  7500 173
10 9000 199
SUBAREA 13 - SOUTH WILLIS CREEK LOCAL AREA ABOVE KREUGER HILL TRIBUTARY
0.51 1.10 0.4 59 30 15 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE KREUGER HILL TRIBUTARY
* DISPLAY POINT
SUBAREA 14 - KREUGER HILL TRIBUTARY ABOVE MOUTH
1.23 2.88 1.5 52 10 7 100
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TITLED COMBINE
SOUTH WILLIS CREEK BELOW KREUGER HILL TRIBUTARY
* DISPLAY POINT
TITLED ROUTE
ROUTE TO RIVER OAKS DRIVE TRIBUTARY
0 0 0 10 1
1     0   0
2   500  13
3  1000  22
4  1500  32
5  2000  40
6  3000  68
7  4500 116
8  6000 181
9  7500 239
10 9000 284
SUBAREA 15 - SOUTH WILLIS CREEK LOCAL AREA ABOVE RIVER OAKS DRIVE TRIBUTARY
0.49 1.09 0.7 32 10 5 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE RIVER OAKS DRIVE TRIBUTARY
* DISPLAY POINT
SUBAREA 16 - RIVER OAKS DRIVE TRIBUTARY ABOVE MOUTH
2.01 2.73 1.6 50 20 10 100
TITLED COMBINE
SOUTH WILLIS CREEK BELOW RIVER OAKS DRIVE TRIBUTARY
* DISPLAY POINT
TITLED ROUTE
ROUTE TO MOUTH
0 0 0 10 1
1     0   0
2   500   7
3  1000  12
4  1500  16
5  2000  21
6  3000  35
7  4500  60
8  6000  93
9  7500 123
10 9000 147
SUBAREA 17 - SOUTH WILLIS CREEK LOCAL AREA ABOVE MOUTH
0.33 1.23 0.6 76 50 25 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE MOUTH
* DISPLAY POINT
TITLED COMBINE
WILLIS CREEK BELOW SOUTH WILLIS CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO OAKPARK DRIVE TRIBUTARY
0 0 0 13 1
1      0   0
2    500  33
3   1000  58
4   1500  76
5   2500 107
6   3500 140
7   4500 176
8   5500 220
9   7000 304
10  8000 372
11 10000 542
12 12000 685
13 15000 852
SUBAREA 18 - WILLIS CREEK LOCAL AREA ABOVE OAKPARK DRIVE TRIBUTARY
0.46 1.26 0.7 50 60 30 100
TITLED COMBINE
WILLIS CREEK ABOVE OAKPARK DRIVE TRIBUTARY
* DISPLAY POINT
SUBAREA 19 - OAKPARK DRIVE TRIBUTARY ABOVE MOUTH
1.20 2.63 1.4 62 30 15 100
TITLED COMBINE
WILLIS CREEK BELOW OAKPARK DRIVE TRIBUTARY
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO LION STADIUM TRIBUTARY (0.85 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 21
SUBAREA 20 - WILLIS CREEK LOCAL AREA ABOVE LION STADIUM TRIBUTARY
0.37 1.36 0.7 37 10 5 100
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TITLED COMBINE
WILLIS CREEK ABOVE LION STADIUM TRIBUTARY
* DISPLAY POINT
SUBAREA 21 - LION STADIUM TRIBUTARY ABOVE MOUTH
2.54 4.16 2.2 16 50 25 100
TITLED COMBINE
WILLIS CREEK BELOW LION STADIUM TRIBUTARY
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.80 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 19
SUBAREA 22 - WILLIS CREEK LOCAL AREA ABOVE MOUTH
0.62 1.85 0.9 110 0 0 100
TITLED COMBINE
WILLIS CREEK ABOVE MOUTH
* DISPLAY POINT
TITLED COMBINE
PECAN BAYOU BELOW WILLIS CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO STEPPES CREEK
0 0 0 10 1
1      0    0
2   1275  230
3   4220  468
4  11500  966
5  18200 1706
6  25900 2727
7  37100 3940
8  46300 4802
9  56000 5642
10 69700 6777
SUBAREA 76 - PECAN BAYOU LOCAL AREA ABOVE STEPPES CREEK
1.27 2.79 1.3 17 0 2 100
TITLED COMBINE
PECAN BAYOU ABOVE STEPPES CREEK
* DISPLAY POINT
SUBAREA 77 - STEPPES CREEK HEADWATERS ABOVE SCS SITE BL#19
5.22 4.53 2.4 40 0 1 100
TITLED ROUTE
STEPPES CREEK BELOW SCS SITE BL#19
0 0 102 17 1
1456      0    6
1460      0   34
1463.5    0  102
1464     19  117
1468     23  267
1472     27  483
1476     30  771
1480     33 1129
1481     33 1229
1482    344 1335
1483   1070 1446
1484   2140 1562
1485   3490 1684
1486   5010 1811
1487   6920 1943
1487.9 9230 2066
1488   9690 2080
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO NORTH FORK OF STEPPES CREEK (4.02 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 97
SUBAREA 78 - STEPPES CREEK LOCAL AREA ABOVE NORTH FORK OF STEPPES CREEK
3.34 4.50 2.5 28 0 0 100
TITLED COMBINE
STEPPES CREEK ABOVE NORTH FORK OF STEPPES CREEK
AREA 79 - NORTH FORK OF STEPPES CREEK HEADWATERS ABOVE SCS SITE BL#20
6.35 4.53 2.2 36 0 1 100
TITLED ROUTE
NORTH FORK OF STEPPES CREEK BELOW SCS SITE BL#20
0 0 108 18 1
1440       0    6
1444       0   28
1448       0   84
1449       0  108
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1452      55  211
1456      61  429
1460      66  757
1464      71 1205
1466      74 1478
1467     441 1629
1468    1290 1789
1469    2540 1958
1470    4110 2135
1471    5970 2319
1471.5  7020 2414
1472    8240 2511
1472.4  9630 2590
1476   45700 3335
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO EAST FORK OF STEPPES CREEK (3.56 RIVER MILES)
0 0 0 2 1
1   0  0
2 1000 86
SUBAREA 80 - NORTH FORK OF STEPPES CREEK LOCAL AREA ABOVE EAST FORK OF SAME
2.20 4.37 2.7 27 0 0 100
TITLED COMBINE
NORTH FORK OF STEPPES CREEK ABOVE EAST FORK OF STEPPES CREEK
SUBAREA 81 - EAST FORK OF STEPPES CREEK ABOVE SCS SITE BL#21
4 10 3.23 2.0 45 0 1 100
TITLED ROUTE
EAST FORK OF STEPPES CREEK BELOW SCS SITE BL#21
0 0 89 20 1
1460       0    2
1464       0   10
1468       0   30
1472       0   72
1473.1     0   89
1476      32  147
1480      36  263
1484      40  425
1488      43  649
1491.7    46  941
1492      63  969
1493     326 1068
1494     789 1177
1495    1430 1297
1496    2240 1428
1497    3170 1572
1498    4290 1732
1498.1  4400 1749
1498.8  5510 1870
1500   10900 2097
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (4.06 RIVER MILES)
0 0 0 2 1
1   0  0
2 1000 98
SUBAREA 82 - EAST FORK OF STEPPES CREEK LOCAL AREA ABOVE MOUTH
4.40 4.56 3.0 30 0 0 100
TITLED COMBINE
EAST FORK OF STEPPES CREEK ABOVE MOUTH
TITLED COMBINE
NORTH FORK OF STEPPES CREEK BELOW EAST FORK OF STEPPES CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.38 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 9
SUBAREA 83 - NORTH FORK OF STEPPES CREEK LOCAL AREA ABOVE MOUTH
0.05 0.53 0.2 65 0 0 100
TITLED COMBINE
NORTH FORK OF STEPPES CREEK ABOVE MOUTH
TITLED COMBINE
STEPPES CREEK BELOW NORTH FORK OF STEPPES CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (4.75 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 120
SUBAREA 84 - STEPPES CREEK LOCAL AREA ABOVE MOUTH
9.48 7.24 2.7 32 0 0 100
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TITLED COMBINE
STEPPES CREEK ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW STEPPES CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO LEWIS CREEK
0 0 0 10 1
1      0    0
2   1275   47
3   4220   96
4  11500  198
5  18200  349
6  25900  559
7  37100  807
8  46300  984
9  56000 1156
10 69700 1388
SUBAREA 85 - LEWIS CREEK HEADWATERS ABOVE SCS SITE BL#25
2.34 2.05 1.1 70 0 1 100
TITLED ROUTE
LEWIS CREEK BELOW SCS SITE BL#25
0 0 20 15 1
1424       0   6
1426.5     0  20
1428      42  35
1432      51 101
1436      58 207
1440      64 357
1442.5    68 474
1443     101 500
1444     319 553
1445     666 608
1446    1130 667
1447    1720 728
1448    2420 793
1449    3210 861
1450.2  5760 947
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (5.07 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 120
SUBAREA 86 - PECAN BAYOU LOCAL AREA "LEWIS CREEK", ABOVE ITS MOUTH
5.44 6.22 2.7 34 0 0 100
TITLED COMBINE
LEWIS CREEK ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW LEWIS CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO DOUDLE CREEK
0 0 0 10 1
1      0     0
2   1275   433
3   4220  1173
4  11500  2608
5  18200  3998
6  25900  5949
7  37100  8838
8  46300 11043
9  56000 13084
10 69700 15613
SUBAREA 87 - PECAN BAYOU LOCAL AREA ABOVE DOUDLE CREEK
9.67 7.01 3.5 4 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE DOUDLE CREEK
* DISPLAY POINT
SUBAREA 88 - DOUDLE CREEK ABOVE MOUTH
15.42 9.09 5.2 30 0 0 100
TITLED COMBINE
PECAN BAYOU BELOW DOUDLE CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO DEVILS RIVER
0 0 0 10 1
1      0    0
2   1275  138
3   4220  321
4  11500  766
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5  18200 1199
6  25900 1687
7  37100 2256
8  46300 2669
9  56000 3087
10 69700 3664
SUBAREA 89 - PECAN BAYOU LOCAL AREA ABOVE DEVILS RIVER
1.52 1.80 0.8 47 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE DEVILS RIVER
* DISPLAY POINT
SUBAREA 90 - DEVILS RIVER ABOVE MOUTH
6.64 7.12 4.4 40 0 0 100
TITLED COMBINE
PECAN BAYOU BELOW DEVILS RIVER
* DISPLAY POINT
TITLED ROUTE
ROUTE TO MACKINALLY CREEK
0 0 0 10 1
1      0    0
2   1275  176
3   4220  409
4  11500  976
5  18200 1526
6  25900 2147
7  37100 2872
8  46300 3398
9  56000 3929
10 69700 4663
SUBAREA 91 - PECAN BAYOU LOCAL AREA ABOVE MACKINALLY CREEK
2.15 2.60 1.3 53 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE MACKINALLY CREEK
* DISPLAY POINT
SUBAREA 92 - MACKINALLY CREEK ABOVE MOUTH
15.46 8.26 4.7 32 0 0 100
TITLED COMBINE
PECAN BAYOU BELOW MACKINALLY CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO PECAN CREEK
0 0 0 10 1
1      0     0
2   1275   400
3   4220   951
4  11500  2272
5  18200  3547
6  25900  4928
7  37100  6521
8  46300  7663
9  56000  8808
10 69700 10387
SUBAREA 93 - PECAN BAYOU LOCAL AREA ABOVE PECAN CREEK
2.62 4.13 1.9 41 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE PECAN CREEK
* DISPLAY POINT
SUBAREA 94 - PECAN CREEK HEADWATERS ABOVE SCS SITE BL#22
2.34 2.63 1.3 69 0 1 100
TITLED ROUTE
PECAN CREEK BELOW SCS SITE BL#22
0 0 50 18 1
1344      0   6
1348      0  14
1352      0  34
1354      0  50
1356     51  70
1360     57 124
1364     63 200
1368     68 302
1372     73 438
1372.5   73 458
1373    117 478
1374    425 520
1375    903 565
1376   1540 613
1377   2340 663
1378   3260 716
1379   4700 771
1379.7 6510 811
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
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TITLED ROUTE
DUMMY ROUTE TO MOUTH (3.14 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 76
SUBAREA 95 - PECAN CREEK LOCAL AREA ABOVE MOUTH
3.54 4.57 2.5 49 0 0 100
TITLED COMBINE
PECAN CREEK ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW PECAN CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO LONG BRANCH
0 0 0 10 1
1      0    0
2   1275  114
3   4220  285
4  11500  608
5  18200  941
6  25900 1349
7  37100 1845
8  46300 2219
9  56000 2635
10 69700 3321
SUBAREA 96 - PECAN BAYOU LOCAL AREA ABOVE LONG BRANCH
5.57 6.65 4.4 35 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE LONG BRANCH
* DISPLAY POINT
SUBAREA 97 - LONG BRANCH HEADWATERS ABOVE SCS SITE BL#23
1.61 2.11 1.0 70 0 1 100
TITLED ROUTE
LONG BRANCH BELOW SCS SITE BL#23
0 0 12 15 1
1348       0   2
1352       0  12
1353.6    41  20
1356      47  39
1360      54  91
1364      61 169
1368      67 271
1369      69 300
1370     164 329
1371     458 361
1372     889 394
1373    1470 429
1374    2190 466
1374.1 2280 470
1375.1 3330 509
* 1N THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (3.13 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 76
SUBAREA 98 - LONG BRANCH LOCAL AREA ABOVE MOUTH
2.25 3.28 1.9 30 0 0 100
TITLED COMBINE
LONG BRANCH ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW LONG BRANCH
* DISPLAY POINT
TITLED ROUTE
ROUTE TO FISK CREEK
0 0 0 10 1
1      0    0
2   1275  204
3   4220  524
4  11500 1271
5  18200 2015
6  25900 2914
7  37100 3996
8  46300 4798
9  56000 5637
10 69700 6897
SUBAREA 99 - PECAN BAYOU LOCAL AREA ABOVE FISK CREEK
3.33 2.83 1.4 59 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE FISK CREEK
* DISPLAY POINT
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SUBAREA 100 - FISK CREEK ABOVE MOUTH
13.44 8.88 4.9 27 0 0 100
TITLED COMBINE
PECAN BAYOU BELOW FISK CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO ROUGH CREEK
0 0 0 10 1
1      0    0
2   1275  281
3   4220  691
4  11500 1704
5  18200 2795
6  25900 3896
7  37100 5285
8  46300 6352
9  56000 7428
10 69700 8866
SUBAREA 101 - PECAN BAYOU LOCAL AREA ABOVE ROUGH CREEK
8.43 6.49 2.7 40 0 3 100
TITLED COMBINE
PECAN BAYOU ABOVE ROUGH CREEK
* DISPLAY POINT
SUBAREA 102 - ROUGH CREEK ABOVE MOUTH
6.86 4.68 2.6 46 0 1 100
TITLED COMBINE
PECAN BAYOU BELOW ROUGH CREEK
* DISPLAY POINT
TITLED ROUTE
ROUTE TO BLANKET CREEK
0 0 0 10 1
1      0    0
2   1275  336
3   4220  801
4  11500 1749
5  18200 2763
6  25900 3763
7  37100 4952
8  46300 5854
9  56000 6741
10 69700 7868
SUBAREA 103 - PECAN BAYOU LOCAL AREA ABOVE BLANKET CREEK
6.51 5.14 2.0 24 0 1 100
TITLED COMBINE
PECAN BAYOU ABOVE BLANKET CREEK
* DISPLAY POINT
* THE "BC" NOTATION FOR THE FOLLOWING SERIES OF SCS FLOODWATER RETARDING SITES
* STANDS FOR BLANKET CREEK.  THE "BL" NOTATION FOR THOSE EARLIER IN THE MODEL
* STANDS FOR BROWNWOOD LATERALS.
SUBAREA 104 - BLANKET CREEK HEADWATERS ABOVE SCS SITE BC#1
3.62 4.88 2.1 24 0 1 100
TITLED ROUTE
BLANKET CREEK BELOW SCS SITE BC#1
0 0 76 17 1
1688       0    8
1692       0   38
1694.3     0   76
1696      13  118
1700      24  268
1704      32  496
1708      38  826
1708.6    39  887
1709      66  929
1710     326 1043
1711     770 1168
1712    1370 1304
1713    2110 1451
1714    2980 1612
1714.2  3170 1646
1715    5020 1786
1716   12900 1974
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#2-A TRIBUTARY (3.64 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 88
SUBAREA 105 - BLANKET CREEK LOCAL AREA ABOVE SCS SITE BC#2-A TRIBUTARY
3.44 4.46 2.4 30 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE SCS SITE BC#2-A TRIBUTARY
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SUBAREA 106 - SCS SITE BC#2-A TRIBUTARY HEADWATERS ABOVE DAMSITE
3.03 2.33 1.3 48 0 1 100
TITLED ROUTE
SCS SITE BC#2-A TRIBUTARY BELOW DAMSITE
0 0 121 16 1
1666      0    8
1670      0   36
1674      0   94
1675.3    0  121
1678     91  190
1682    102  334
1686    112  548
1687.7  116  664
1688    137  686
1689    438  764
1690    984  847
1691   1710  936
1692   2610 1033
1693.3 4020 1168
1694   6200 1247
1694.2 7650 1269
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (2.19 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 53
SUBAREA 107 - SCS SITE BC#2-A TRIBUTARY LOCAL AREA ABOVE MOUTH
2.72 3.68 2.0 46 0 0 100
TITLED COMBINE
SCS SITE BC#2-A TRIBUTARY ABOVE MOUTH
TITLED COMBINE
BLANKET CREEK BELOW SCS SITE BC#2-A TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#3 TRIBUTARY (1.87 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 45
SUBAREA 108 - BLANKET CREEK LOCAL AREA ABOVE SCS SITE BC#3 TRIBUTARY
2.97 4.52 2.3 44 5 3 100
TITLED COMBINE
BLANKET CREEK ABOVE SCS SITE BC#3 TRIBUTARY
SUBAREA 109 - SCS SITE BC#3 TRIBUTARY HEADWATERS ABOVE DAMSITE
1.28 1.78 0.6 50 0 1 100
TITLED ROUTE
SCS SITE BC#3 TRIBUTARY BELOW DAMSITE
0 0 27 17 1
1660       0    2
1664       0   18
1665.1     0   27
1668       7   62
1672      12  148
1676      15  288
1678.6    16  411
1679      45  432
1680     317  488
1681     792  548
1682    1410  613
1683    2190  682
1683.7  2810  734
1684    3130  757
1684.3  3740  781
1685    7100  838
1688   35000 1117
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MERGER WITH SCS SITE BC#4 TRIBUTARY (1.17 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 28
SUBAREA 110 - SCS SITE BC#4 TRIBUTARY HEADWATERS ABOVE DAMSITE
0.97 1.53 0.7 55 0 1 100
TITLED ROUTE
SCS SITE BC#4 TRIBUTARY BELOW DAMSITE
0 0 21 13 1
1668       0   4
1671.5     0  23
1672       3  26
1676       8  82
1680      11 184
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1684      13 334
1685     182 379
1686     581 427
1687    1160 479
1688    1880 535
1688.7  2480 577
1689.3  3640 614
1692   32500 803
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MERGER WITH SCS SITE BC#3 TRIBUTARY (1.13 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 27
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM SCS SITES BC#3 AND BC#4
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.94 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 47
SUBAREA 111 - SCS SITE BC#3 TRIBUTARY LOCAL AREA ABOVE MOUTH
1.65 3.18 1.9 31 10 5 100
TITLED COMBINE
SCS SITE BC#3 TRIBUTARY ABOVE MOUTH
TITLED COMBINE
BLANKET CREEK BELOW SCS SITE BC#3 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO NEXT MAJOR RIGHT BANK TRIBUTARY (2.81 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 68
SUBAREA 112 - BLANKET CREEK LOCAL AREA ABOVE RIGHT BANK TRIBUTARY
2.06 4.69 3.1 35 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE RIGHT BANK TRIBUTARY
SUBAREA 113 - RIGHT BANK TRIBUTARY ABOVE MOUTH
4.20 6.54 4.3 29 0 0 100
TITLED COMBINE
BLANKET CREEK BELOW RIGHT BANK TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#6 TRIBUTARY (1.42 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 34
SUBAREA 114 - SCS SITE BC#6 TRIBUTARY HEADWATERS ABOVE DAMSITE
5.01 5.16 2.8 40 0 1 100
TITLED ROUTE
SCS SITE BC#6 TRIBUTARY BELOW DAMSITE
0 0 98 18 1
1548       0    9
1552       0   23
1556       0   55
1559.1     0   98
1560      12  115
1564      28  227
1568      37  395
1572      45  615
1576      51  913
1577.7    54 1071
1578      80 1101
1579     461 1208
1580    1130 1324
1581    2030 1449
1582    3140 1584
1583    4460 1729
1583.8 5660 1852
1584.6 9540 1981
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.91 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
TITLED COMBINE
COMBINING ROUTED SCS SITE BC#6 OUTFLOWS WITH THOSE FROM MAINSTEM
SUBAREA 115 - BLANKET CREEK LOCAL AREA TO BELOW SCS SITE BC#6 TRIBUTARY
1.55 2.54 0.9 61 0 0 100
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TITLED COMBINE
BLANKET CREEK BELOW SCS SITE BC#6 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#7 TRIBUTARY (1.67 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 40
SUBAREA 116 -  SCS SITE BC#7 TRIBUTARY HEADWATERS ABOVE DAMSITE
1.02 1.23 0.5 86 0 1 100
TITLED ROUTE
SCS SITE BC#7 TRIBUTARY BELOW DAMSITE
0 0 24 15 1
1556       0   0
1560       0   4
1564       0  20
1564.6     0  24
1568       6  54
1572       9 116
1576      11 218
1576.2    11 225
1577     120 251
1578     479 287
1579    1010 327
1580    1690 370
1580.3  1910 383
1581.4  4120 437
1584   27900 585
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.48 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 36
TITLED COMBINE
COMBINING ROUTED SCS SITE BC#7 OUTFLOWS WITH THOSE FROM MAINSTEM
SUBAREA 117 - BLANKET CREEK LOCAL AREA TO BELOW SCS SITE BC#7 TRIBUTARY
1.18 2.05 1.2 59 0 0 100
TITLED COMBINE
BLANKET CREEK BELOW SCS SITE BC#7 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO CAMP CREEK (3.89 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 94
SUBAREA 118 -  SCS SITE BC#8 TRIBUTARY HEADWATERS ABOVE DAMSITE
2.19 2.91 1.5 43 0 1 100
TITLED ROUTE
SCS SITE BC#8 TRIBUTARY BELOW DAMSITE
0 0 51 15 1
1504       0    4
1508       0   20
1511.4     0   51
1512      22   58
1516      26  128
1520      30  250
1524      33  438
1524.7    33  478
1525      65  495
1526     504  558
1527    1275  625
1528    2300  698
1528.7  3140  752
1529.4  4800  808
1532   33800 1045
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.55 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 38
TITLED COMBINE
COMBINING ROUTED SCS SITE BC#8 OUTFLOWS WITH THOSE FROM MAINSTEM
SUBAREA 119 - BLANKET CREEK LOCAL AREA ABOVE CAMP CREEK
3.91 5.89 3.1 26 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE CAMP CREEK
SUBAREA 120 - CAMP CREEK HEADWATERS ABOVE SCS SITE BC#10
2.49 2.50 1.2 53 0 1 100
TITLED ROUTE
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CAMP CREEK BELOW SCS SITE BC#10
0 0 72 16 1
1632      0    0
1636      0    8
1640      0   28
1644      0   72
1648     13  150
1652     19  270
1656     23  436
1658.8   26  580
1659     33  591
1660    263  650
1661    716  712
1662   1350  778
1663   2140  848
1664   3070  922
1664.3 3380  946
1665.2 5880 1018
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#11 (3.59 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 87
SUBAREA 121 - CAMP CREEK LOCAL AREA ABOVE SCS SITE BC#11
5.70 4.99 2.2 31 0 1 100
TITLED COMBINE
CAMP CREEK ABOVE SCS SITE BC#11
TITLED ROUTE
CAMP CREEK BELOW SCS SITE BC#11
0 0 94 17 1
1532       0   12
1536       0   42
1539       0   94
1540      83  120
1544      95  260
1548     106  472
1552     116  788
1556     125 1238
1557     520 1374
1558    1440 1518
1559    2750 1672
1560    4370 1835
1561    6200 2008
1562    8300 2194
1562.1  8520 2213
1563.3 13000 2456
1564   19500 2607
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (2.57 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 62
SUBAREA 122 - CAMP CREEK LOCAL AREA ABOVE MOUTH
1.41 3.03 2.0 37 0 0 100
TITLED COMBINE
CAMP CREEK ABOVE MOUTH
TITLED COMBINE
BLANKET CREEK BELOW CAMP CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#9 TRIBUTARY (2.27 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 55
SUBAREA 123 -  SCS SITE BC#9 TRIBUTARY HEADWATERS ABOVE DAMSITE
2.32 2.75 1.6 41 0 1 100
TITLED ROUTE
SCS SITE BC#9 TRIBUTARY BELOW DAMSITE
0 0 88 16 1
1452      0    0
1456      0    4
1460      0   16
1464      0   42
1467.8    0   88
1468     19   91
1472     21  183
1476     23  343
1479.6   25  568
1480     54  598
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1481    330  680
1482    807  770
1483   1440  867
1484   2230  972
1484.3 2500 1005
1485   4970 1085
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.25 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 6
TITLED COMBINE
COMBINING ROUTED SCS SITE BC#9 OUTFLOWS WITH THOSE FROM MAINSTEM
SUBAREA 124 - BLANKET CREEK LOCAL AREA TO BELOW SCS SITE BC#9 TRIBUTARY
2.50 3.47 1.7 32 0 0 100
TITLED COMBINE
BLANKET CREEK BELOW SCS SITE BC#9 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO DRY BLANKET CREEK (2.60 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 63
SUBAREA 125 - BLANKET CREEK LOCAL AREA ABOVE DRY BLANKET CREEK
1.84 3.40 2.1 33 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE DRY BLANKET CREEK
SUBAREA 126 - DRY BLANKET CREEK HEADWATERS ABOVE SCS SITE BC#12
7.58 4.49 2.5 40 0 1 100
TITLED ROUTE
DRY BLANKET CREEK BELOW SCS SITE BC#12
0 0 140 19 1
1600       0    0
1604       0   10
1608       0   54
1611.8     0  140
1612      48  146
1616      54  290
1620      60  498
1624      66  782
1628      71 1150
1630.3    73 1402
1631     252 1484
1632     951 1607
1633    2000 1736
1634    3340 1871
1635    4920 2011
1636    6890 2157
1636.9  8710 2294
1638.1 12300 2484
1639.9 29400 2791
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#13 TRIBUTARY (1.30 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 32
SUBAREA 127 - SCS SITE BC#13 TRIBUTARY HEADWATERS ABOVE DAMSITE
4.21 2.76 1.5 60 0 1 100
TITLED ROUTE
SCS SITE BC#13 TRIBUTARY BELOW DAMSITE
0 0 93 18 1
1584       0    0
1588       0    2
1592       0   16
1596       0   56
1598.3     0   93
1600      85  128
1604      96  240
1608     107  402
1612     116  624
1615     123  840
1616     380  922
1617     988 1010
1618    1840 1102
1619    2910 1198
1620    4200 1300
1621    5590 1406
1621.5  6380 1461
1622.7 10000 1484
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* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.56 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 14
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM SCS SITE BC#13 WITH THOSE FROM MAINSTEM
SUBAREA 128 - DRY BLANKET CREEK LOCAL AREA TO BELOW SCS SITE BC#13 TRIBUTARY
0.70 1.59 0.8 62 0 0 100
TITLED COMBINE
DRY BLANKET CREEK BELOW SCS SITE BC#13 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#14 TRIBUTARY (1.89 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 46
SUBAREA 129 - SCS SITE BC#14 TRIBUTARY HEADWATERS ABOVE DAMSITE
3.19 3.16 1.7 56 0 2 100
TITLED ROUTE
SCS SITE BC#14 TRIBUTARY BELOW DAMSITE
0 0 75 19 1
1556      0    0
1560      0    4
1564      0   16
1568      0   42
1571      0   75
1572      8   90
1576     18  166
1580     24  278
1584     29  440
1588     34  660
1589.2   35  737
1590    205  791
1591    766  861
1592   1600  935
1593   2670 1013
1594   3960 1094
1594.7 4920 1153
1595.9 8240 1260
1596   8830 1269
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.56 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 14
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM SCS SITE BC#14 WITH THOSE FROM MAINSTEM
SUBAREA 130 - DRY BLANKET CREEK LOCAL AREA TO BELOW SCS SITE BC#14 TRIBUTARY
2.26 4.32 2.1 45 0 0 100
TITLED COMBINE
DRY BLANKET CREEK BELOW SCS SITE BC#14 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO TURKEY PEAK MOUNTAIN TRIBUTARY (1.87 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 45
SUBAREA 131 - DRY BLANKET CREEK LOCAL AREA ABOVE TURKEY PEAK MOUNTAIN TRIBUTARY
2.49 4.57 2.1 40 0 0 100
TITLED COMBINE
DRY BLANKET CREEK ABOVE TURKEY PEAK MOUNTAIN TRIBUTARY
SUBAREA 132 - TURKEY PEAK MOUNTAIN TRIBUTARY ABOVE MOUTH
3.20 4.28 2.7 56 0 0 100
TITLED COMBINE
DRY BLANKET CREEK BELOW TURKEY PEAK MOUNTAIN TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO DIRT HOUSE BRANCH (5.31 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 130
SUBAREA 133 - DRY BLANKET CREEK LOCAL AREA ABOVE DIRT HOUSE BRANCH
5.26 7.20 3.8 29 0 0 100
TITLED COMBINE
DRY BLANKET CREEK ABOVE DIRT HOUSE BRANCH
SUBAREA 134 - NORTH FORK OF DIRT HOUSE BRANCH HEADWATERS ABOVE SCS SITE BC#15
4.12 3.64 1.6 57 0 1 100
TITLED ROUTE
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NORTH FORK OF DIRT HOUSE BRANCH BELOW SCS SITE BC#15
0 0 124 15 1
1500       0    0
1504       0   20
1508       0   52
1512       0  124
1516      20  244
1520      29  420
1524      35  670
1528      41 1000
1529     297 1094
1530     904 1194
1531    1760 1300
1532    2820 1412
1533    4110 1531
1533.8  5200 1631
1535.3 10100 1835
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MERGER WITH SAND SPRING BRANCH (2.10 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 51
SUBAREA 135 - SAND SPRING BRANCH HEADWATERS ABOVE SCS SITE BC#16
1.72 1.91 1.2 80 0 1 100
TITLED ROUTE
SAND SPRING BRANCH BELOW SCS SITE BC#16
0 0 20 15 1
1468       0   0
1472       0   4
1476       0  20
1480       8  54
1484      12 112
1488      15 200
1492      17 324
1493      17 362
1494     184 404
1495     578 449
1496    1140 498
1497    1850 550
1497.9  2620 601
1498.5  3510 636
1500   12800 732
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MERGER WITH NORTH FORK OF DIRT HOUSE BRANCH (0.60 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 15
TITLED COMBINE
COMBINING ROUTED OUTFLOWS ALONG SAND SPRING BRANCH AND NORTH FORK DIRT HOUSE
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH OF DIRT HOUSE BRANCH (1.25 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 30
SUBAREA 136 - DIRT HOUSE BRANCH LOCAL AREA ABOVE MOUTH
3.08 6.08 3.6 41 0 0 100
TITLED COMBINE
DIRT HOUSE BRANCH ABOVE MOUTH
TITLED COMBINE
DRY BLANKET CREEK BELOW DIRT HOUSE BRANCH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH OF DRY BLANKET CREEK (0.59 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 14
SUBAREA 137 - DRY BLANKET CREEK LOCAL AREA ABOVE MOUTH
0.12 0.72 0.4 110 0 0 100
TITLED COMBINE
DRY BLANKET CREEK ABOVE MOUTH
TITLED COMBINE
BLANKET CREEK BELOW DRY BLANKET CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO CONFLUENCE OF RIGHT AND LEFT BANK TRIBUTARIES (0.39 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 9
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SUBAREA 138 - RIGHT BANK TRIBUTARY ABOVE MOUTH
1.97 3.97 2.3 47 0 0 100
SUBAREA 139 - LEFT BANK TRIBUTARY ABOVE MOUTH
1.73 2.76 1.3 67 0 0 100
TITLED COMBINE
COMBINING RIGHT AND LEFT BANK TRIBUTARIES
TITLED COMBINE
BLANKET CREEK BELOW CONFLUENCE OF RIGHT AND LEFT BANK TRIBUTARIES
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO GROVES BRANCH (1.84 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 45
SUBAREA 140 - BLANKET CREEK LOCAL AREA ABOVE GROVES BRANCH
2.98 4.36 1.8 41 2 1 100
TITLED COMBINE
BLANKET CREEK ABOVE GROVES BRANCH
SUBAREA 141 - GROVES BRANCH ABOVE MOUTH
2.04 3.66 2.0 62 0 1 100
TITLED COMBINE
BLANKET CREEK BELOW GROVES BRANCH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO KELLY BRANCH (2.81 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 68
SUBAREA 142 - KELLY BRANCH HEADWATERS ABOVE SCS SITE BC#20
4.38 3.90 2.1 55 0 1 100
TITLED ROUTE
KELLY BRANCH BELOW SCS SITE BC#20
0 0 85 21 1
1376        0    0
1380        0   15
1384        0   33
1388        0   69
1389.2      0   85
1392       16  129
1396       25  217
1400       31  337
1404       37  487
1408       41  665
1412       45  869
1416       49 1099
1417      340 1161
1418     1050 1225
1419     2060 1290
1420     3350 1357
1421     4820 1426
1422     6480 1497
1422.2   6850 1511
1423.5  10500 1606
1424    13200 1643
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.31 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 32
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM KELLY BRANCH AND MAINSTEM
SUBAREA 143 - BLANKET CREEK LOCAL AREA TO BELOW KELLY BRANCH
3.85 3.33 1.7 25 0 0 100
TITLED COMBINE
BLANKET CREEK BELOW KELLY BRANCH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO BEE BRANCH (0.30 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 7
SUBAREA 144 - BLANKET CREEK LOCAL AREA INCLUDING BEE BRANCH
6.02 8.46 3.3 32 2 1 100
TITLED COMBINE
BLANKET CREEK BELOW BEE BRANCH
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO POMPEY CREEK (10.32 RIVER MILES)
0 0 0 2 1
1    0   0
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2 1000 250
SUBAREA 145 - BLANKET CREEK LOCAL AREA ABOVE POMPEY CREEK
12.03 11.14 5.7 12 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE POMPEY CREEK
SUBAREA 146 - POMPEY CREEK HEADWATERS ABOVE SCS SITE BC#17A-1
15.30 7.09 2.5 31 0 1 100
TITLED ROUTE
POMPEY CREEK BELOW SCS SITE BC#17A-1
0 0 257 21 1
1508        0    4
1512        0   30
1516        0  100
1519.5      0  200
1520        0  218
1521        0  257
1524      142  414
1528      156  724
1532      170 1152
1536      182 1732
1540      194 2492
1542.8    201 3139
1543      225 3189
1544      940 3449
1545     2330 3723
1546     4250 4012
1547     6620 4315
1548     9230 4484
1549    12100 4819
1549.7 14400 5062
1551.2 24300 5611
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO FIRST LEFT BANK TRIBUTARY (0.20 RIVER MILES)
0 0 0 2 1
1    0 0
2 1000 5
SUBAREA 147 - FIRST LEFT BANK TRIBUTARY ABOVE MOUTH
1.80 2.70 1.8 73 0 0 100
TITLED COMBINE
POMPEY CREEK BELOW FIRST LEFT BANK TRIBUTARY BELOW SCS SITE BC#17A-1
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#18 TRIBUTARY (2.14 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 52
SUBAREA 148 - SCS SITE BC#18 TRIBUTARY ABOVE DAMSITE
4.31 4.81 2.4 42 0 1 100
TITLED ROUTE
SCS SITE BC#18 TRIBUTARY BELOW DAMSITE
0 0 67 21 1
1480        0    0
1484        0    5
1488        0   21
1492        0   55
1493        0   67
1496       17  115
1500       26  215
1504       33  369
1508       38  579
1512       43  851
1512.5     43  890
1513      111  930
1514      564 1015
1515     1300 1104
1516     2260 1199
1517     3430 1299
1518     4760 1404
1518.3   5170 1437
1519.2   7500 1538
1520    13100 1632
1524    65300 2156
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.72 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 17
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM SCS SITE #18 WITH THAT ALONG MAINSTEM
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SUBAREA 149 - POMPEY CREEK LOCAL AREA TO BELOW SCS SITE BC#18 TRIBUTARY
4.10 3.11 1.9 61 0 0 100
TITLED COMBINE
POMPEY CREEK BELOW SCS SITE BC#18 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO SCS SITE BC#19 TRIBUTARY (3.66 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 89
SUBAREA 150 - SCS SITE BC#19 TRIBUTARY ABOVE DAMSITE
7.66 5.45 2.8 42 0 1 100
TITLED ROUTE
SCS SITE BC#19 TRIBUTARY BELOW DAMSITE
0 0 108 20 1
1448        0    4
1452        0   24
1456        0   86
1456.9      0  108
1460       53  206
1464       59  396
1468       64  664
1472       69 1006
1476       74 1426
1480       79 1940
1481      425 2086
1482     1240 2242
1483     2390 2408
1484     3830 2585
1485     5450 2771
1486     7345 2967
1486.2   7750 3007
1487.4 11900 3256
1488   17400 3386
1492   87800 4358
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (2.23 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 54
TITLED COMBINE
COMBINING ROUTED OUTFLOWS FROM SCS SITE #19 WITH THAT ALONG MAINSTEM
SUBAREA 151 - POMPEY CREEK LOCAL AREA TO BELOW SCS SITE BC#19 TRIBUTARY
7.64 5.64 2.0 30 0 0 100
TITLED COMBINE
POMPEY CREEK BELOW SCS SITE BC#19 TRIBUTARY
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (10.00 RIVER MILES)
0 0 0 2 1
1    0   0
2 1000 240
SUBAREA 152 - POMPEY CREEK LOCAL AREA ABOVE MOUTH
24.20 13.06 6.9 22 0 0 100
TITLED COMBINE
POMPEY CREEK ABOVE MOUTH
TITLED COMBINE
BLANKET CREEK BELOW POMPEY CREEK
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (1.94 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 47
SUBAREA 153 - BLANKET CREEK LOCAL AREA ABOVE MOUTH
0.76 2.98 2.0 34 0 0 100
TITLED COMBINE
BLANKET CREEK ABOVE MOUTH
TITLED COMBINE
PECAN BAYOU BELOW BLANKET CREEK
* DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
ROUTE TO STATE HIGHWAY 573 (0.57 RIVER MILES)
0 0 0 10 1
1      0    0
2   1275   50
3   4220  120
4  11500  261
5  18200  413
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6  25900  562
7  37100  740
8  46300  875
9  56000 1007
10 69700 1176
SUBAREA 154 - PECAN BAYOU LOCAL AREA ABOVE STATE HIGHWAY 573
0.61 1.81 0.9 100 0 0 100
TITLED COMBINE
PECAN BAYOU AT STATE HIGHWAY 573
DISPLAY POINT
* THIS IS THE LOCATION OF THE USGS GAGE "PECAN BAYOU NEAR MULLIN", GAGE NO.
* 08143600 (OCT'67-PRESENT).  IT HAS A STATED DRAINAGE AREA OF 2,073 SQ.MILE.
TITLED ROUTE
ROUTE TO CONFLUENCE WITH COLORADO RIVER
0 0 0 10 1
1      0     0
2   1275  1228
3   4220  3064
4  11500  6616
5  18200 10141
6  25900 14079
7  37100 19054
8  46300 22621
9  56000 26043
10 69700 30705
```

WILLIS CREEK WATERSHED MODEL:

```
* NOTE:  THIS MODEL HAS HIGHER INFILTRATION RATES FOR THE FREQUENT EVENTS,
*        THAN DOES THE GENERAL PECAN BAYOU WATERSHED MODEL.
BROWNWOOD - FEASIBILITY STUDY - MAY 2001
DATA
SCHEMATIC DIAGRAM DISPLAY = ON
POINT DISCHARGE DISPLAY = OFF
UHG DATA DISPLAY = OFF
MODIFIED UHG DISPLAY = ON
COMPUTED PROBABILITY DISPLAY = ON
EXPECTED PROBABILITY DISPLAY = ON
LOCAL PRINTOUT
3 3 3 3 3 3 3 3 3
COMBINE PRINTOUT
3 3 3 3 3 3 3 3 3
ROUTE PRINTOUT
3 3 3 3 3 3 3 3 3
DATA
1 YEAR RAINFALL
1.0  1.3  1.58  1.75  2.15  2.54  2.875 3.4   3.7   4
2 YEAR RAINFALL
1.37 1.77 2.01  2.25  2.69  3.19  3.715 4.23  4.6   4.9
5 YEAR RAINFALL
1.72 2.29 2.77  3.045 3.655 4.37  5.085 5.5   5.9   6.4
10 YEAR RAINFALL
1.97 2.64 3.29  3.61  4.365 5.21  5.97  6.65  7.1   7.6
25 YEAR RAINFALL
2.32 3.15 3.845 4.275 5.185 6.11  7.09  8.05  8.6   9.1
50 YEAR RAINFALL
2.60 3.54 4.55  4.83  5.72  6.90  8.05  9.1   9.8  10.45
100 YEAR RAINFALL
2.87 3.93 4.875 5.40  6.53  7.81  9.10 10.45 11.0  11.5
500 YEAR RAINFALL
3.87 5.31 6.58  7.29  8.82 10.54 12.29 14.11 14.85 15.53
HYDRO-35 RAINFALL
0.994 1.77 1.842 3.93
SPF RAINFALL
14.15
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
DATA
UHG DATA
IMPERVIOUSNESS
PERCENT SAND
NO PRINTOUT
SUBAREA 1 - WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#3
8.53 4.66 1.8 32 0 1 100
```

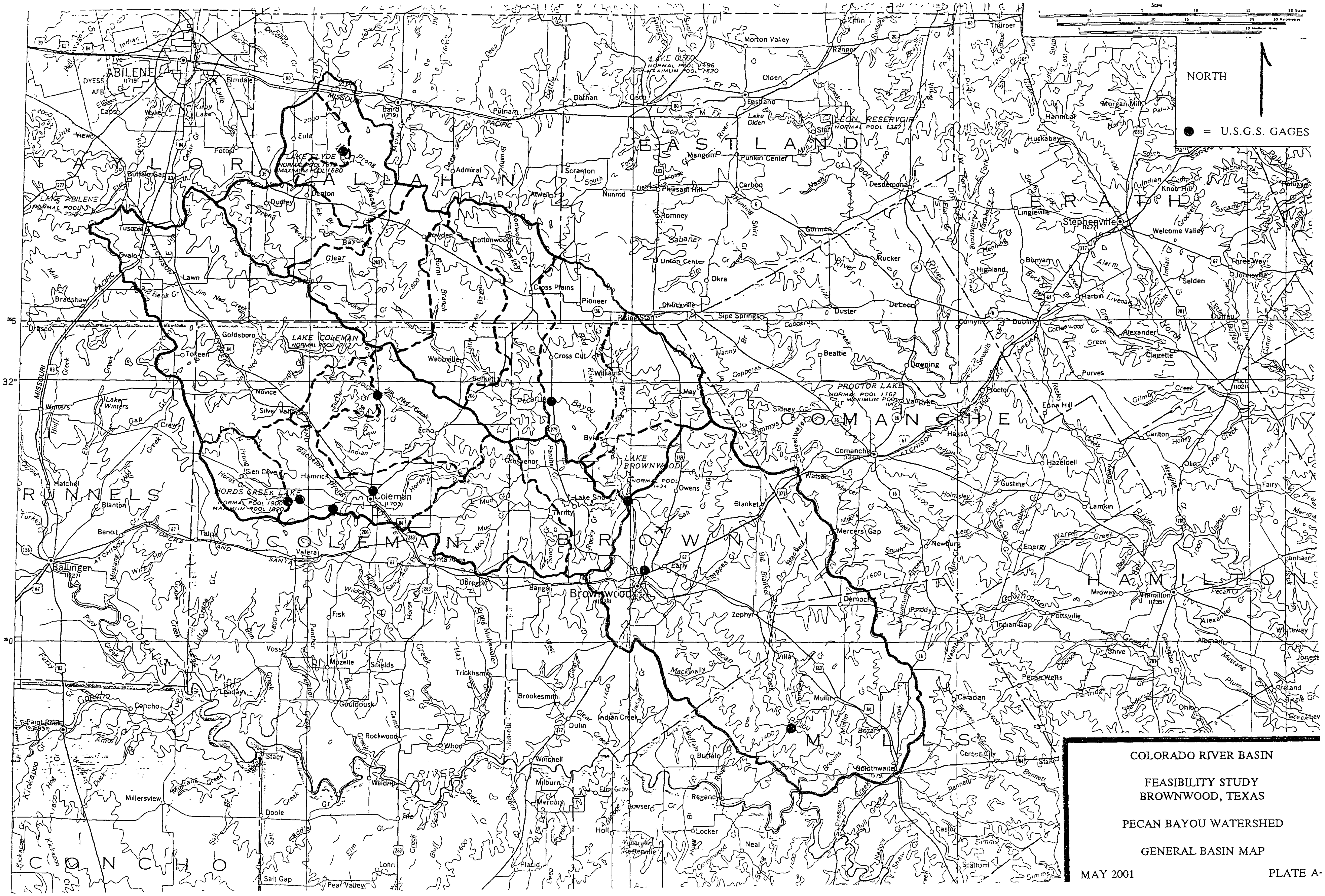
```
DATA
1ST RIL & FAV
100  100  100  100  100  100  100  100  100
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
100  100  100  100  100  100  100  100  100
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
SUBAREA 2 - QUARRY (NOTE INFINITE RAINFALL LOSSES)
0.67 2 1 1 0 0 100
DATA
1ST RIL & FAV
1.50 1.50 1.30 1.12 0.95 0.84 0.75 0.50 0.50
0.20 0.20 0.16 0.14 0.12 0.10 0.07 0.05 0.05
2ND RIL & FAV
2.10 2.10 1.80 1.50 1.30 1.10 0.90 0.60 0.60
0.26 0.26 0.21 0.18 0.15 0.13 0.10 0.08 0.08
TITLED COMBINE
WILLIS CREEK ABOVE SCS SITE BL#3
TITLED ROUTE
WILLIS CREEK BELOW SCS SITE BL#3
0 0 400 26 1
1420       0  152
1422.1     0  198
1424       0  244
1428       0  364
1429       0  400
1432     104  520
1436     110  718
1400     116  956
1444     122 1230
1448     128 1546
1452     133 1918
1456     138 2388
1460     143 3012
1464     148 3874
1465     586 4136
1466    1200 4418
1467    3090 4718
1468    4910 5038
1469    7160 5378
1470    9460 5740
1471   12200 6125
1472   15000 6532
1473   18300 6953
1474   21700 7380
1474.4 23100 7553
1476.7 35500 8565
DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE 2400 FEET, TO END OF HEC-2 MODEL (0.45 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 11
TITLED ROUTE
ROUTE TO US HIGHWAY 377
0 0 0 13 1
1      0   0
2    500   5
3   1000   7
4   1500  10
5   2500  15
6   3445  20
7   6000  39
8   7449  50
9  10095  69
10 12297  82
11 16285 105
12 20343 132
13 24307 152
SUBAREA 3 - WILLIS CREEK LOCAL AREA ABOVE US HIGHWAY 377
0.70 1.38 0.7 32 20 10 100
TITLED COMBINE
WILLIS CREEK AT US HIGHWAY 377
DISPLAY POINT
TITLED ROUTE
ROUTE TO RAILROAD SPUR
0 0 0 13 1
1      0   0
2    500  10
3   1000  16
```

```
4   1500  21
5   2500  30
6   4000  50
7   6000  77
8   8000 103
9  12000 132
10 15000 157
11 20000 195
12 25000 231
13 30000 264
SUBAREA 4 - WILLIS CREEK LOCAL AREA ABOVE RAILROAD SPUR
0.49 0.75 0.4 130 30 15 100
TITLED COMBINE
WILLIS CREEK AT RAILROAD SPUR
DISPLAY POINT
TITLED ROUTE
ROUTE TO CUSTER ROAD
0 0 0 13 1
1      0    0
2     500   30
3   1000   59
4   1500   96
5   2500  159
6   4000  268
7   6000  355
8   8000  433
9  12000  575
10 15000  711
11 20000  836
12 25000  951
13 30000 1078
SUBAREA 5 - WILLIS CREEK LOCAL AREA ABOVE CUSTER ROAD
0.93 1.74 0.8 31 40 20 100
TITLED COMBINE
WILLIS CREEK AT CUSTER ROAD
DISPLAY POINT
TITLED ROUTE
ROUTE TO SOUTH WILLIS CREEK
0 0 0 13 1
1      0    0
2     500   43
3   1000   71
4   1500  104
5   2500  174
6   4000  333
7   6000  468
8   8000  545
9  12000  793
10 15000  940
11 20000 1167
12 25000 1368
13 30000 1569
SUBAREA 6 - WILLIS CREEK LOCAL AREA ABOVE SOUTH WILLIS CREEK
1.23 2.32 1.2 26 70 35 100
TITLED COMBINE
WILLIS CREEK ABOVE SOUTH WILLIS CREEK
DISPLAY POINT
SUBAREA 7 - SOUTH WILLIS CREEK HEADWATERS ABOVE SCS SITE BL#4A
0.84 1.27 0.6 97 0 2 100
TITLED ROUTE
SOUTH WILLIS CREEK BELOW SCS SITE BL#4A
0 0 38 18 1
1448       0   6
1451       0  18
1452       0  24
1453.8     0  38
1456      81  62
1460      93 134
1464     105 248
1465.5   109 299
1466     154 316
1467     450 352
1468     932 389
1469    1560 428
1470    2330 469
1471    3210 513
1472    4270 559
1472.3  4590 574
1473.3  6490 623
1476   29100 764
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
```

```
TITLED ROUTE
DUMMY ROUTE TO COUNTRY CLUB TRIBUTARY (1.56 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 38
SUBAREA 8 - SOUTH WILLIS CREEK LOCAL AREA ABOVE COUNTRY CLUB TRIBUTARY
1.81 2.17 1.0 57 2 1 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE COUNTRY CLUB TRIBUTARY
SUBAREA 9 - COUNTRY CLUB TRIBUTARY HEADWATERS ABOVE SCS SITE BL#4B
1.14 1.07 0.4 130 0 2 100
TITLED ROUTE
COUNTRY CLUB TRIBUTARY BELOW SCS SITE BL#4B
0 0 47 15 1
1452       0    4
1454       0   15
1456.8     0   47
1460      87  114
1464      99  242
1468     110  428
1469     330  486
1470     862  548
1471    1620  616
1472    2560  689
1473    3690  767
1474    4940  851
1474.5  5690  896
1475.6  8440  999
1476   10700 1038
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO COUNTRY CLUB LAKE (0.90 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
SUBAREA 10 - COUNTRY CLUB TRIBUTARY LOCAL AREA ABOVE COUNTRY CLUB LAKE DAM
0.79 0.82 0.3 220 2 6 100
TITLED COMBINE
COUNTRY CLUB TRIBUTARY AT COUNTRY CLUB LAKE DAM
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.91 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 22
SUBAREA 11 - COUNTRY CLUB TRIBUTARY LOCAL AREA ABOVE MOUTH
0.78 1.62 0.9 72 2 1 100
TITLED COMBINE
COUNTRY CLUB TRIBUTARY ABOVE SOUTH WILLIS CREEK
TITLED COMBINE
SOUTH WILLIS CREEK BELOW COUNTRY CLUB TRIBUTARY (AT STATE HWY. 45, MILAM DRIVE)
DISPLAY POINT
TITLED ROUTE
ROUTE TO MORRIS SHEPPARD DRIVE
0 0 0 10 1
1     0   0
2   500   8
3  1000  15
4  1500  23
5  2000  45
6  3000  85
7  4500 114
8  6000 148
9  7500 180
10 9000 217
SUBAREA 12 - SOUTH WILLIS CREEK LOCAL AREA ABOVE MORRIS SHEPPARD DRIVE
0.75 1.30 0.6 62 10 5 100
TITLED COMBINE
SOUTH WILLIS CREEK AT MORRIS SHEPPARD DRIVE
DISPLAY POINT
TITLED ROUTE
ROUTE TO KREUGER HILL TRIBUTARY
0 0 0 10 1
1     0   0
2   500  15
3  1000  27
4  1500  40
5  2000  54
6  3000  82
7  4500 116
8  6000 145
```

```
9  7500 173
10 9000 199
SUBAREA 13 - SOUTH WILLIS CREEK LOCAL AREA ABOVE KREUGER HILL TRIBUTARY
0.51 1.10 0.4 59 30 15 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE KREUGER HILL TRIBUTARY
DISPLAY POINT
SUBAREA 14 - KREUGER HILL TRIBUTARY ABOVE MOUTH
1.23 2.88 1.5 52 10 7 100
TITLED COMBINE
SOUTH WILLIS CREEK BELOW KREUGER HILL TRIBUTARY
DISPLAY POINT
TITLED ROUTE
ROUTE TO RIVER OAKS DRIVE TRIBUTARY
0 0 0 10 1
1     0   0
2   500  13
3  1000  22
4  1500  32
5  2000  40
6  3000  68
7  4500 116
8  6000 181
9  7500 239
10 9000 284
SUBAREA 15 - SOUTH WILLIS CREEK LOCAL AREA ABOVE RIVER OAKS DRIVE TRIBUTARY
0.49 1.09 0.7 32 10 5 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE RIVER OAKS DRIVE TRIBUTARY
DISPLAY POINT
SUBAREA 16 - RIVER OAKS DRIVE TRIBUTARY ABOVE MOUTH
2.01 2.73 1.6 50 20 10 100
TITLED COMBINE
SOUTH WILLIS CREEK BELOW RIVER OAKS DRIVE TRIBUTARY
DISPLAY POINT
TITLED ROUTE
ROUTE TO MOUTH
0 0 0 10 1
1     0   0
2   500   7
3  1000  12
4  1500  16
5  2000  21
6  3000  35
7  4500  60
8  6000  93
9  7500 123
10 9000 147
SUBAREA 17 - SOUTH WILLIS CREEK LOCAL AREA ABOVE MOUTH
0.33 1.23 0.6 76 50 25 100
TITLED COMBINE
SOUTH WILLIS CREEK ABOVE MOUTH
DISPLAY POINT
TITLED COMBINE
WILLIS CREEK BELOW SOUTH WILLIS CREEK
DISPLAY POINT
TITLED ROUTE
ROUTE TO OAKPARK DRIVE TRIBUTARY
0 0 0 13 1
1      0   0
2    500  22
3   1000  34
4   1500  44
5   2500  65
6   4000  97
7   6000 152
8   8000 236
9  12000 462
10 15000 550
11 20000 692
12 25000 814
13 30000 923
SUBAREA 18 - WILLIS CREEK LOCAL AREA ABOVE OAKPARK DRIVE TRIBUTARY
0.46 1.26 0.7 50 60 30 100
TITLED COMBINE
WILLIS CREEK ABOVE OAKPARK DRIVE TRIBUTARY
DISPLAY POINT
SUBAREA 19 - OAKPARK DRIVE TRIBUTARY ABOVE MOUTH
1.20 2.63 1.4 62 30 15 100
TITLED COMBINE
WILLIS CREEK BELOW OAKPARK DRIVE TRIBUTARY
```

```
DISPLAY POINT
TITLED ROUTE
ROUTE TO LION STADIUM TRIBUTARY
0 0 0 13 1
1      0    0
2    500   38
3   1000   64
4   1500   89
5   2500  133
6   4000  196
7   6000  276
8   8000  358
9  12000  520
10 15000  657
11 20000  914
12 25000 1130
13 30000 1320
SUBAREA 20 - WILLIS CREEK LOCAL AREA ABOVE LION STADIUM TRIBUTARY
0.37 1.36 0.7 37 10 5 100
TITLED COMBINE
WILLIS CREEK ABOVE LION STADIUM TRIBUTARY
DISPLAY POINT
SUBAREA 21 - LION STADIUM TRIBUTARY ABOVE MOUTH
2.54 4.16 2.2 16 50 25 100
TITLED COMBINE
WILLIS CREEK BELOW LION STADIUM TRIBUTARY
DISPLAY POINT
* IN THE FOLLOWING DUMMY ROUTE, ASSUME V=5
TITLED ROUTE
DUMMY ROUTE TO MOUTH (0.80 RIVER MILES)
0 0 0 2 1
1    0  0
2 1000 19
SUBAREA 22 - WILLIS CREEK LOCAL AREA ABOVE MOUTH
0.62 1.85 0.9 110 0 0 100
TITLED COMBINE
WILLIS CREEK ABOVE MOUTH
DISPLAY POINT
```



COLORADO RIVER BASIN

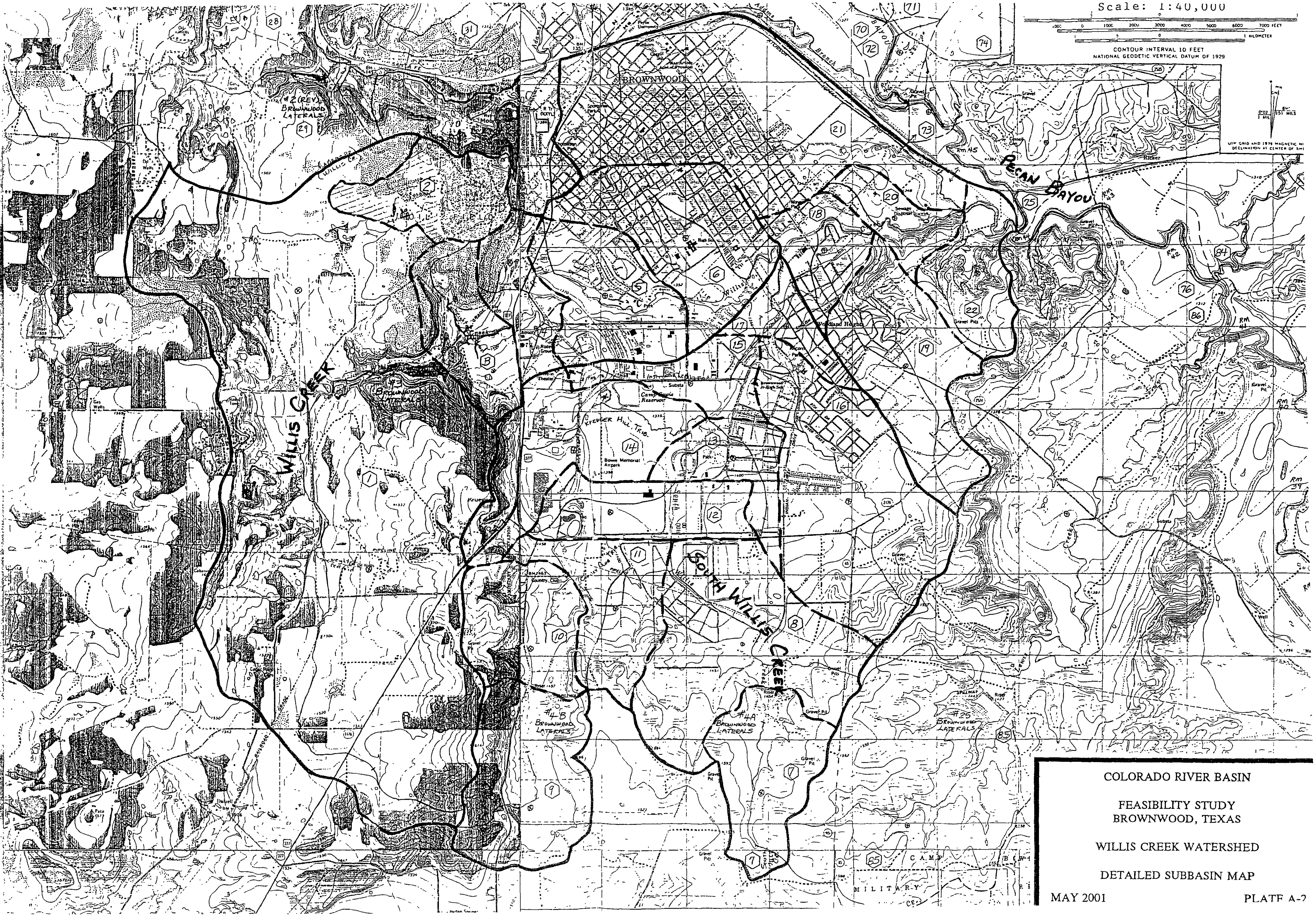
FEASIBILITY STUDY
BROWNWOOD, TEXAS

PECAN BAYOU WATERSHED

GENERAL BASIN MAP

MAY 2001

PLATE A-



COLORADO RIVER BASIN

FEASIBILITY STUDY
BROWNWOOD, TEXAS

WILLIS CREEK WATERSHED

DETAILED SUBBASIN MAP

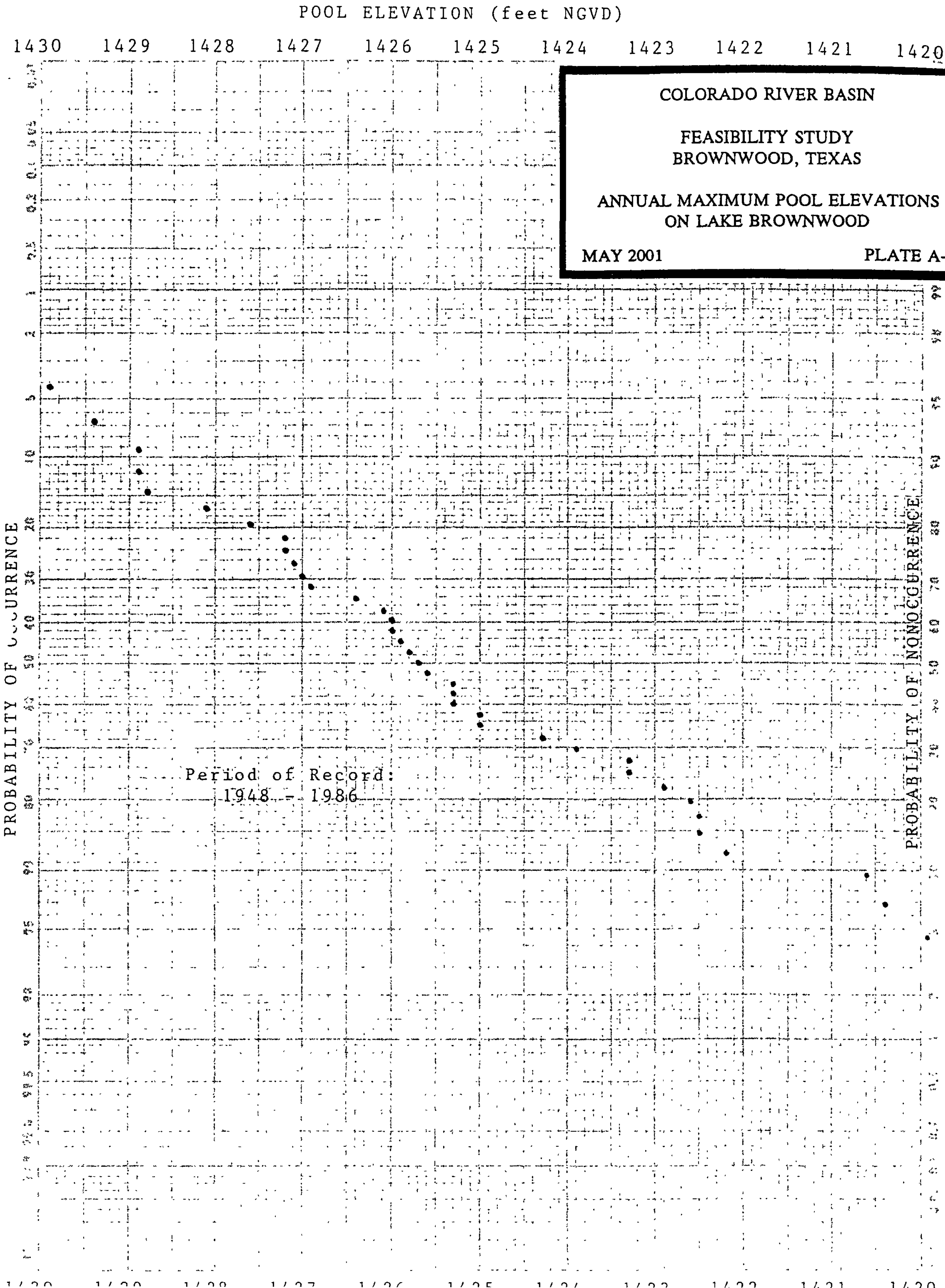
MAY 2001 PLATE A-2

COLORADO RIVER BASIN

FEASIBILITY STUDY
BROWNWOOD, TEXAS

ANNUAL MAXIMUM POOL ELEVATIONS
ON LAKE BROWNWOOD

MAY 2001 PLATE A-3

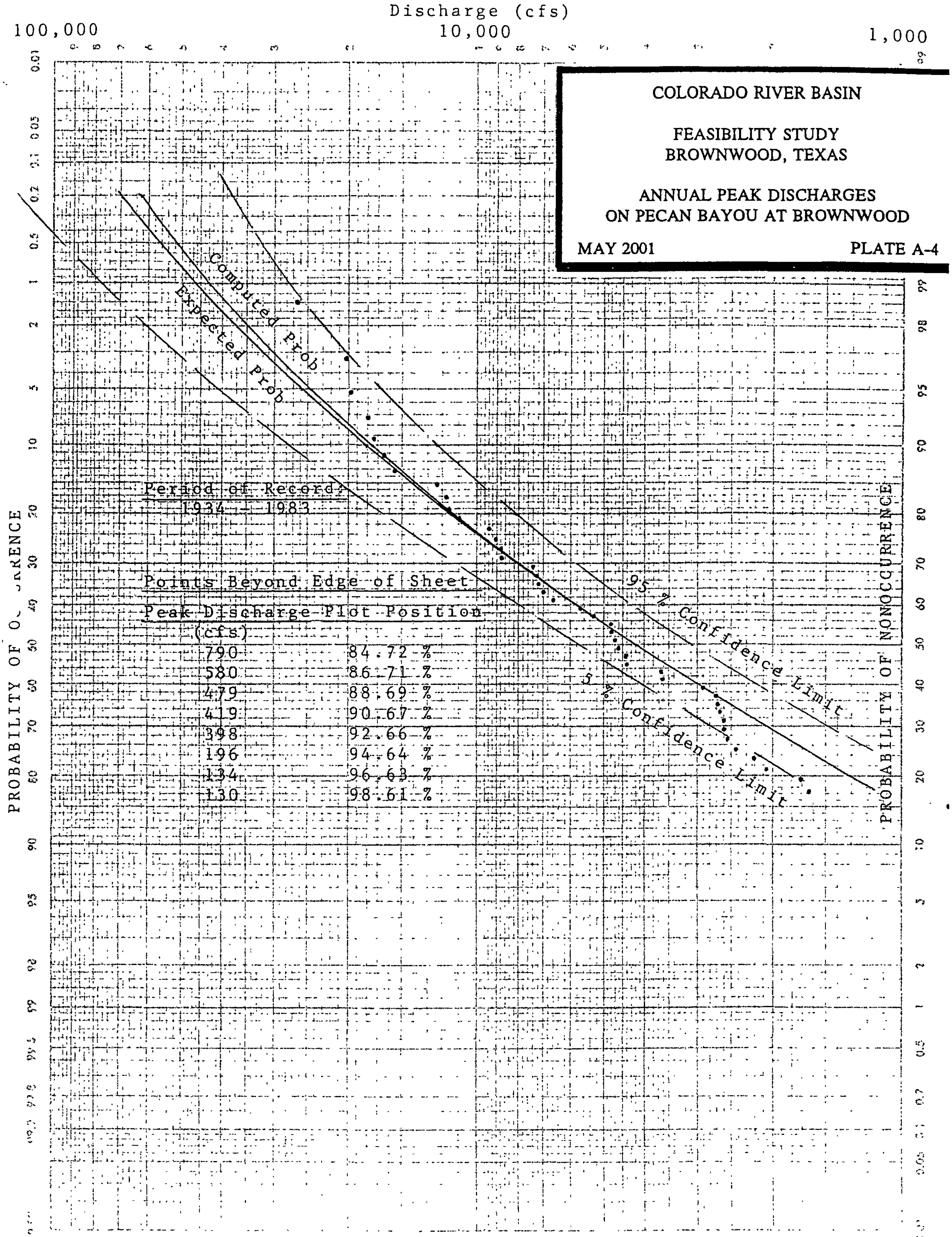


COLORADO RIVER BASIN

FEASIBILITY STUDY
BROWNWOOD, TEXAS

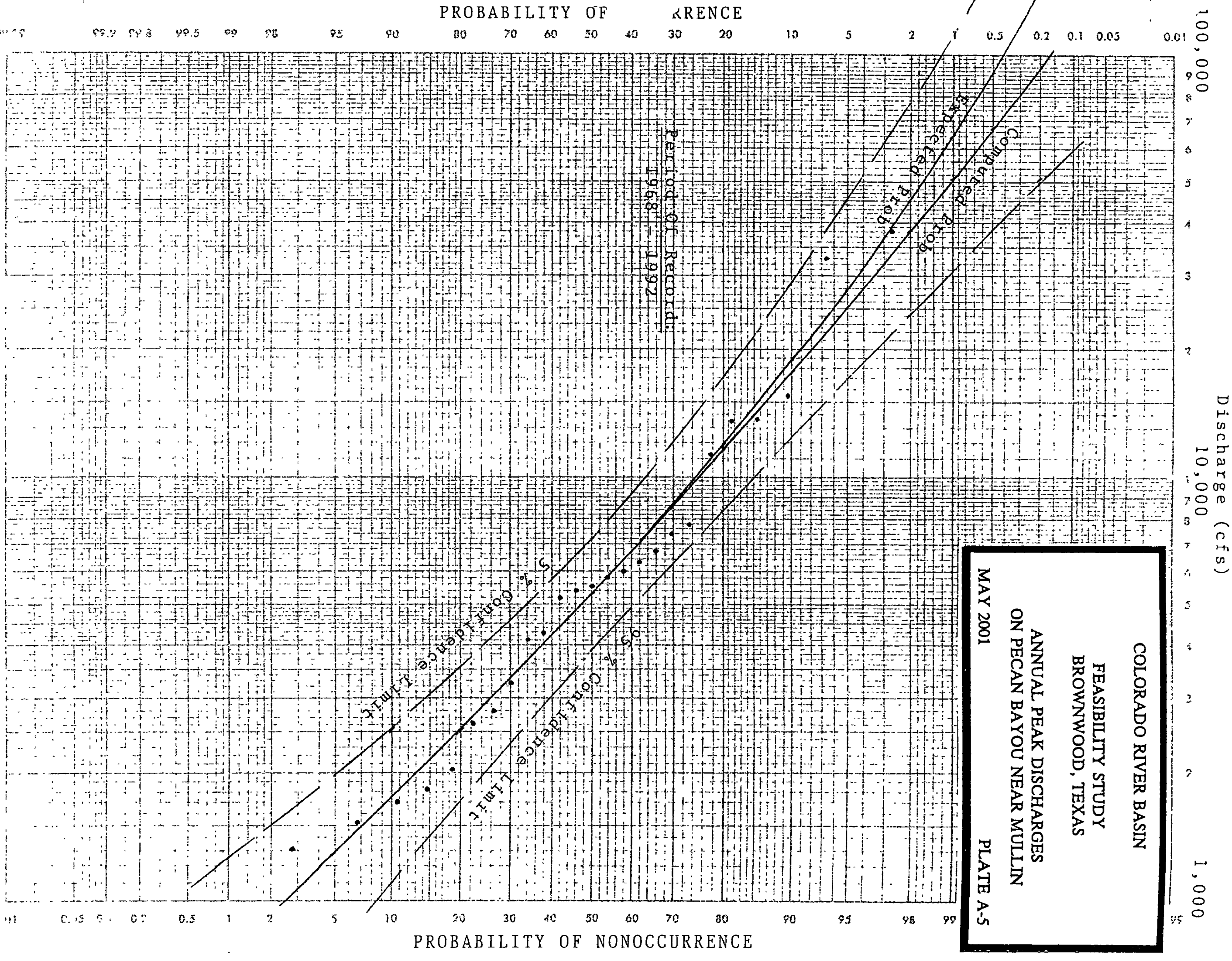
ANNUAL PEAK DISCHARGES
ON PECAN BAYOU AT BROWNWOOD

MAY 2001 PLATE A-4



Points Beyond Edge of Sheet

Peak Discharge (cfs)	Plot Position
790	84.72 %
580	86.71 %
479	88.69 %
419	90.67 %
398	92.66 %
196	94.64 %
134	96.63 %
130	98.61 %

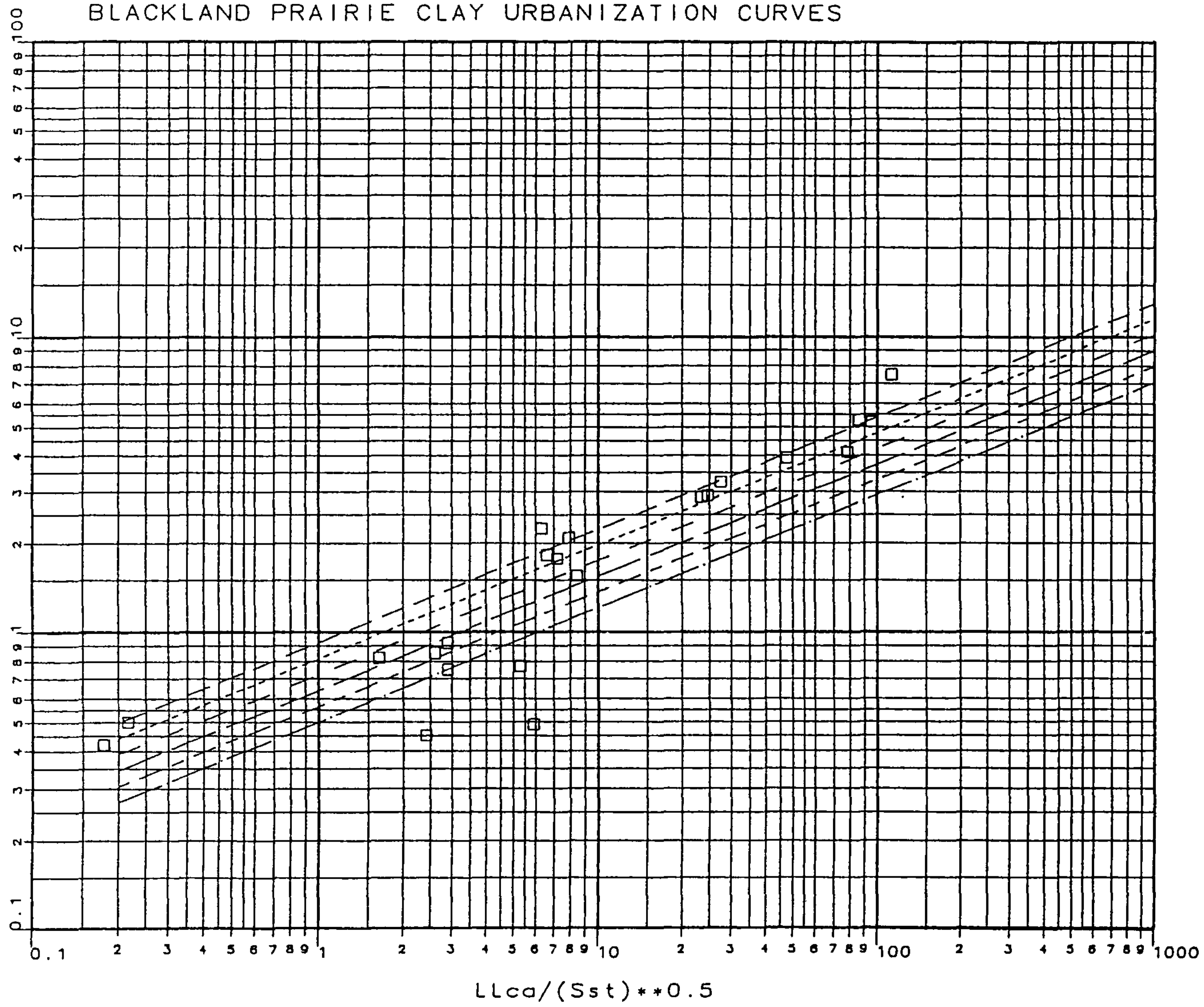


COLORADO RIVER BASIN
FEASIBILITY STUDY
BROWNWOOD, TEXAS
ANNUAL PEAK DISCHARGES
ON PECAN BAYOU NEAR MULLIN

MAY 2001

PLATE A-5

OF ENGINEERS U.S. ARMY



LEGEND

□ DATA POINTS FROM STORM REPRODUCTION STUDIES

—— · 100% URBANIZATION

— — · 80% URBANIZATION

—— · 60% URBANIZATION

— — 40% URBANIZATION

------ 20% URBANIZATION

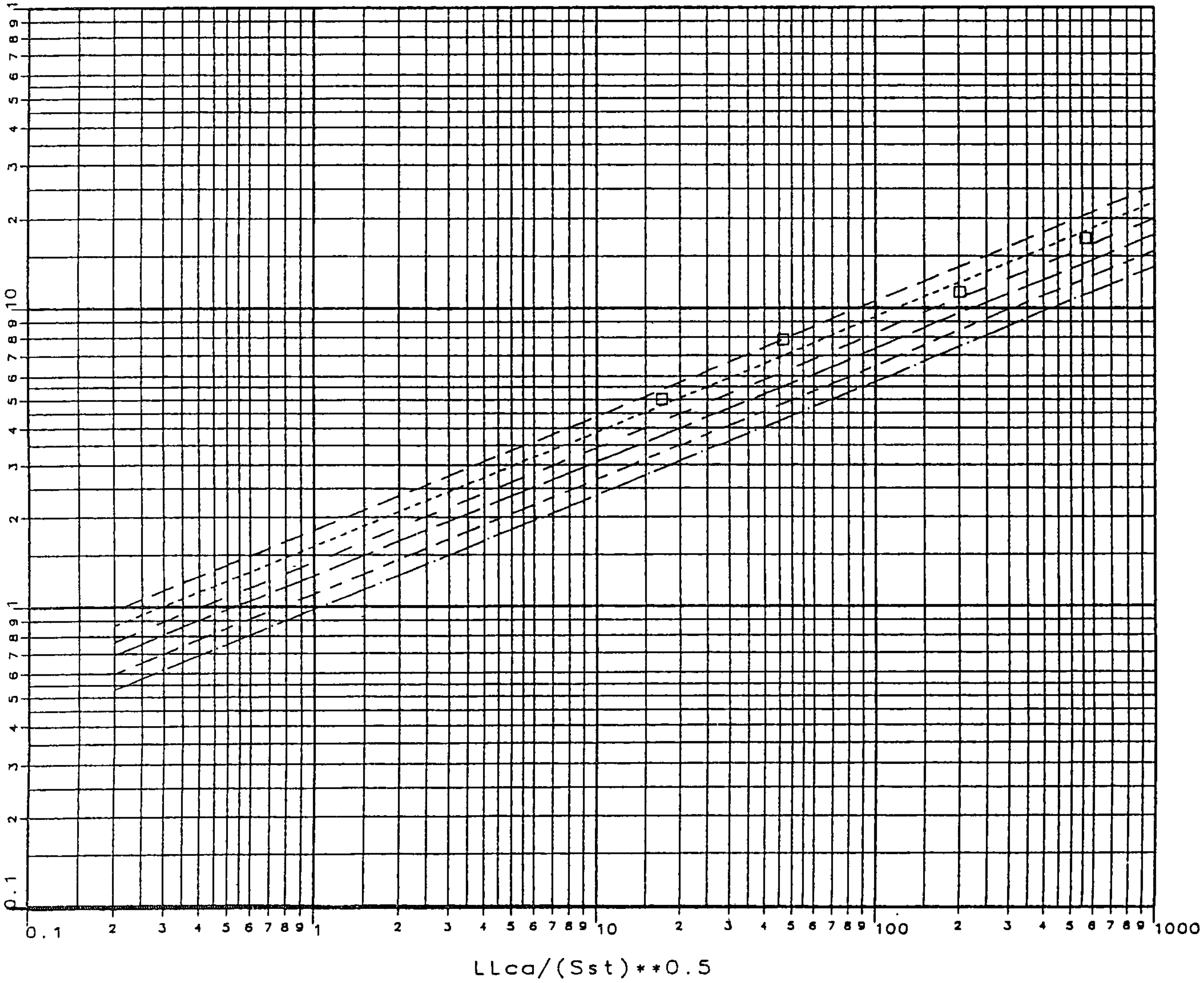
— — 0% URBANIZATION

COLORADO RIVER BASIN
FEASIBILITY STUDY
BROWNWOOD, TEXAS
BLACKLAND PRAIRIE CLAY
URBANIZATION CURVES

MAY 2001

PLATE A-6

CROSS TIMBER SANDY LOAM URBANIZATION CURVES



LEGEND

- ☐ DATA POINTS FROM STORM REPRODUCTION STUDIES
- —— - 100% URBANIZATION
- — — - 80% URBANIZATION
- —— - 60% URBANIZATION
- — — 40% URBANIZATION
- ------ 20% URBANIZATION
- — — 0% URBANIZATION

COLORADO RIVER BASIN
FEASIBILITY STUDY
BROWNWOOD, TEXAS
CROSS TIMBER SANDY LOAM
URBANIZATION CURVES

MAY 2001

PLATE A-7

SUB-APPENDIX B

HYDRAULICS

SUB-APPENDIX B

HYDRAULIC ANALYSIS

GENERAL BACKGROUND

This feasibility study consists of hydraulic analyses of Pecan Bayou and Willis Creek. During the reconnaissance phase of this study, hydraulic analyses were also performed on South Willis Creek.

Pecan Bayou is a major left bank tributary of the Colorado River. Its watershed is located near the geographical center of the State of Texas and comprises portions of Taylor, Callahan, Eastland, Runnels, Coleman, Brown, Comanche, and Mills Counties. Its mouth is located a few miles west of Goldthwaite, in Mills County. This study was focused on the reach extending from a few miles upstream of Lake Brownwood to a few miles downstream from the City of Brownwood, all within Brown County. In the immediate study area, Pecan Bayou flows generally in a northwest-to-southeast direction

Willis Creek is a relatively minor right bank tributary of Pecan Bayou. Its watershed is located along the southern edge of the City of Brownwood and comprises a substantial portion of the now abandoned "Camp Bowie" World War I army base. Its mouth is located near river mile 44 on Pecan Bayou, several hundred feet downstream from the Atchison-Topeka-Sante Fe Railway crossing. This study has focused on the reach through the southern portions of the developed area of the City of Brownwood. In the immediate study area, Willis Creek flows generally in a west-to-east direction.

South Willis Creek is a major right bank tributary of Willis Creek. Its watershed is located immediately south of the City of Brownwood and occupies a substantial portion of the old "Camp Bowie" lands. Its mouth is located a few hundred feet downstream from the Fourth Street (Southside Drive) crossing, within the City of Brownwood. When this tributary was evaluated during the reconnaissance phase of study, the focus was on the few reaches having existing development. For the most part, this was limited to a relatively short reach of the floodplain used for a mobile home park.

For purposes of these studies, existing condition water surface profiles were developed for a wide range of hypothetical storm frequencies, including the: "1-, 2-, 5-, 10-, 25-, 50-, 100-, 500-, and 1000-year" events. During the course of this study, policy changes have been made to encourage the representation of these events in terms of their annual exceedance probability, rather than their effective recurrence interval. Accordingly, each of these (other than the "1-year" event) are now often referred to as the: "50-, 20-, 10-, 4-, 2-, 1-, and 0.1-percent" annual chance exceedance events, respectively.

HYDRAULIC MODELS

The US Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) computer program "HEC-2" was used to simulate backwater conditions along the study streams. Valley cross sections for these models were extracted from detailed topographic mapping. During the reconnaissance phase of study, an earlier set of such mapping was available in hardcopy format. Generalized backwater models were developed with an acceptable cross section spacing for that type of study. Detailed information regarding bridge openings and culvert dimensions was obtained during site visits by USACE hydraulic engineers, during that study phase. No substantial changes to bridge and/or culvert dimensions has occurred in the immediate study areas of Pecan Bayou and Willis Creek, during the course of the reconnaissance and feasibility phases of study.

At about the time that the feasibility study phase was initiated, the City of Brownwood had contracted for updated detailed topographic mapping for their entire community, and the initial area of coverage included the overwhelming majority of the immediate study area for this feasibility study. In all reaches except those along South Willis Creek (which was excluded since economically feasible projects were not discovered during the reconnaissance study phase), the new topographic data was used as a basis for updated backwater modeling. In the case of the Pecan Bayou floodplain, cross section data was extracted manually, from hardcopy versions of the recent detailed topography. In the case of Willis Creek, this data was extracted using the "GEOPAK" terrain software in combination with "Intergraph MicroStation". This involved the development of a cross section layout in plan view, after which the "GEOPAK" program was able to use a standard triangular irregular network ("tin") model of elevation data, to derive cross section points.

Much older field-surveyed cross section data was available for the reach of Pecan Bayou extending downstream from the City of Brownwood, to near its confluence with the Colorado River. These surveyed sections were developed back in April 1946, but would still more than adequately represent the valley shape downstream from the City of Brownwood.

For purposes of this study, all bridges and culverts were assumed to be free of any substantially accumulated debris and/or sediment, other than the normal bottom sediment that was already clearly represented on the detailed topographic mapping. Bridges measured during a site visit during the reconnaissance phase of study included: FM 2126 (and its relief opening), the Atchison-Topeka-Sante Fe Railway (and its relief opening), Woodson Road, and US Highway 67/377 (and its relief opening) all along Pecan Bayou; Austin Avenue, Fourth Street (Southside Drive), Fourteenth Street (Custer Road), a RR spur, Crockett Drive, and US Highway 377, all along Willis Creek; and Fourth Street (Southside Drive), Stephen Austin Drive, Morris Sheppard Drive, Milam Drive, and FM Loop 45, all along South Willis Creek.

RECONNAISSANCE STUDY PHASE INVESTIGATIONS

LIMITS OF STUDY

For hydraulic purposes, the limits of the study area along Pecan Bayou extended from near its mouth to the tailwater side of the Lake Brownwood Dam (River Mile 56.6). Willis Creek's study area extended from near its mouth to the upstream side of the US Highway 377 crossing (River Mile 6.3). South Willis Creek's study area extended from near its mouth to the upstream side of the FM Loop 45 crossing (River Mile 2.7).

EXISTING CONDITIONS

PECAN BAYOU

Several construction changes in recent history have been made along the study reach of Pecan Bayou. The Atchison-Topeka-Sante Fe Railway bridge has been rebuilt adjacent to, but downstream of the original location. It was both raised and extended in length. The Woodson Road bridge has been rebuilt, but it would appear that the change would have little if any effect upon hydraulic conditions. The US Highway 67/377 bridge has been widened, in terms of its number of lanes. Significant additional urbanization has also taken place along the frontage of US Highway 67/377.

In the study reach, the Pecan Bayou channel typically has a top width ranging from about 150 to 225 feet, and a depth ranging from 20 to 35 feet. Valley cross sections necessary to adequately convey the significantly rare hypothetical flood events range between one and two miles in length. The channel flow capacity is generally less than that necessary to pass a "10-year" (or 10 percent annual chance exceedance) event, in the developed reach adjacent to US Highway 67/377.

The assigned Manning's roughness coefficients along Pecan Bayou generally range up to 0.055 in the channel and from 0.055 to 0.060 in the overbanks.

WILLIS CREEK

Bridges along Willis Creek include: a pier-and-beam span at Austin Avenue; a set of concrete box culverts at both the Fourth Street (Southside Drive) and Fourteenth Street (Custer Road) crossings; a standard trestle at the RR spur; an arched rock structure (actually supported on semicircular corrugated metal pipe arches) at Crockett Drive; and another set of concrete box culverts at the US Highway 377 crossing. Of these structures, the crossing at Fourteenth Street (Custer Road) appears to have the most limited capacity, relative to the potential flood damage impacts, once the capacity is exceeded. Similarly limited capacity at the Fourth Street (Southside Drive) culverts is less threatening, since the roadway profile is set basically at normal ground level, providing for ample overtopping conveyance at relatively low depths.

In the study reach, the Willis Creek channel typically has a top width ranging from about 40 to 135 feet, and a depth ranging from 4 to 11 feet. Valley cross sections necessary to adequately convey the significantly rare hypothetical flood events range between one-half and one mile in length. The channel flow capacity is generally less than that necessary to pass a "10-year" (or 10 percent annual chance exceedance) event, in most of the developed reaches.

The assigned Manning's roughness coefficients along Willis Creek generally range from 0.035 to 0.050 in the channel and from 0.050 to 0.080 in the overbanks.

SOUTH WILLIS CREEK

South Willis Creek has a concrete box culvert crossing at Fourth Street (Southside Drive) and arched rock culvert crossings (constructed identically to the previously mention Crockett Drive crossing on Willis Creek) at Stephen Austin Drive, Morris Sheppard Drive, Milam Drive, and FM Loop 45. These arched rock crossings are generally less efficient hydraulically than the concrete box culverts, primarily due to the large corrugations in the supporting semicircular metal pipe arches. However, since existing condition flood damages were found to be quite limited along the South Willis Creek reaches during the reconnaissance study phase, none of these crossings were recommended for replacement. In fact no structural or non-structural solutions were found to be sufficient from an economic standpoint, to support more detailed hydraulic analysis efforts during the feasibility study phase.

In the study reach, the South Willis Creek channel typically has a top width ranging from about 50 to 125 feet, and a depth ranging from 8 to 10 feet. Valley cross sections necessary to adequately convey the significantly rare hypothetical flood events range between one-fourth and one-half mile in length. The channel flow capacity is generally less than that necessary to pass a "10-year" (or 10 percent annual chance exceedance) event, in the few developed reaches.

The assigned Manning's roughness coefficients along South Willis Creek generally range around 0.035 in the channel and from 0.060 to 0.070 in the overbanks.

IMPROVED CONDITIONS

PECAN BAYOU

The investigated plan included major channel enlargement over a 7,520-foot reach extending downstream from the US Highway 67/377 crossing and a significant enlargement of the Woodson Road bridge opening. This grass-lined, trapezoidal channel was configured to have 3H:1V side slopes. However, these side slopes were steepened slightly (to about 2.7H:1V) in the transition through the Woodson Road reach.

WILLIS CREEK

The investigated plan included major channel enlargement over selected reaches as follows: a 1,315-foot reach extending downstream from Austin Avenue; a 1,650-foot reach extending downstream from the Fourth Street (Southside Drive); and a 10,300-foot reach extending upstream from the Fourth Street (Southside Drive). A grass-lined, trapezoidal channel modification was considered in each reach. The plan also included the installation of four additional box culverts (9 feet high by 7 feet wide) at the Fourteenth Street (Custer Road) crossing.

The first (most downstream) reach was configured to have 3.5H:1V and 3H:1V side slopes on its left and right banks, respectively, and a 30-foot bottom width. The second (middle) reach was configured to have 3H:1V side slopes and a 40-foot bottom width. The third (most upstream) reach was configured to have 3H:1V side slopes and a 50-foot bottom width.

SOUTH WILLIS CREEK

The investigated plan included major channel enlargement over a 975-foot reach generally straddling the Stephen Austin Drive crossing. This grass-lined, trapezoidal channel was configured: to have 1.5H:1V side slopes and a 90-foot bottom width.

As the study proceeded, it was determined that flood damage reduction benefits were far too limited to provide for economic justification of a structural alternative along South Willis Creek. Accordingly, this stream was not investigated further in the subsequent feasibility study phase.

SEDIMENTATION/DEGRADATION EVALUATION

Under existing conditions, these streams appear to be stable and are experiencing neither significant sedimentation nor degradation. Lake Brownwood generally performs a sediment-trapping function along Pecan Bayou. Natural stream bottom slopes (gradients), in the reaches being considered for potential modification, are relatively flat. An evaluation of the change in channel flow velocities for the improved conditions indicates that although speeds would be increased in some locations, most of these increases are relatively small. The improved channel flow velocities should be within the range of acceptability for grass-lined modifications. Riprap-lining of the channel bottom and bank may be required in a few, selected locations. However, no conditions are anticipated which would significantly affect economic justification of these projects.

FEASIBILITY STUDY PHASE INVESTIGATIONS

LIMITS OF STUDY

Pecan Bayou's overall study area extends from its mouth to the Lake Brownwood Dam. However, the detailed study reach for consideration of potential structural modifications, extends from near FM 2126 to a short distance upstream of the developed lands on the north side of US Highway 67/377. Willis Creek's overall study area extends from its mouth to the US Highway 377 crossing. Hydraulic analyses were not performed on South Willis Creek, during the feasibility study phase.

EXISTING CONDITIONS

No significant alterations to the terrain and/or bridge and culvert dimensions have taken place since the reconnaissance phase of study, in the immediate study reaches along both Pecan Bayou and Willis Creek. Limited descriptions are provided in the section titled "Reconnaissance Study Phase Investigations". The following descriptions also deal with the definition of reaches having substantial enough existing condition flood damages to have the potential for providing economic justification of structural and/or non-structural solutions.

PECAN BAYOU

A very significant difference between the reconnaissance phase and feasibility phase backwater modeling relates to the level of detail applied to address the split flow situation which exists throughout the upper damage reach. The right (southwestern) overbank flow path provided by the Pecan Bayou Slough (often referred to as Adams Slough) is separated from the primary Pecan Bayou channel flow path, for the more frequent events. This topographic condition was handled in a fashion whereby the overall valley cross sections were severed at the shallow ridge line between the two flow paths, and a pair of parallel models was developed. Computed water surface elevations at the junction points (both at the downstream and upstream end of the split flow reach) were manually forced to match, by utilizing a "trial and error" solution scheme based on the discharge variable. The downstream junction is located at the point where the Pecan Bayou Slough reenters the Pecan Bayou channel, about 14,000 feet downstream from the US Highway 67/377 bridge, when measured along the Pecan Bayou Channel. The upstream junction is located a few thousand feet upstream from the US Highway 67/377 bridge. A concrete channel dam located about 290 feet upstream from the bridge, significantly contributes to the backwater effects in this upper reach of the detailed study area, especially for the more frequent flood events. The subsequent surcharges in water surface elevation within the Pecan Bayou channel in turn contribute to greater percentages of total flow being directed into the split flow path, via the Pecan Bayou Slough. This effect becomes minimized for the more rare events. As a result, it was determined that computed water surface elevations for the more rare events would be based on the output using the overall valley model, rather than the split flow version. Existing condition water surface profiles along Pecan Bayou are presented on Plate B-1.

Three economic damage centers were identified along Pecan Bayou. These include: the wastewater treatment plant, situated on Willis Creek, but within the floodplain of Pecan Bayou; a residential neighborhood in southeastern Brownwood, situated in the far right (southwest) overbank; and a multi-use (residential, commercial, industrial, public, etc.) area in northeastern Brownwood, situated along the reach extending from Woodson Road to a few thousand feet upstream of the US Highway 67/377 crossing.

WILLIS CREEK

One primary difference between the reconnaissance phase and feasibility phase backwater modeling relates to the use of the City of Brownwood's updated topographic mapping. In this particular case, the availability of the new mapping provided the opportunity for development of a detailed backwater model, beginning near the mouth of Willis Creek. During the reconnaissance phase of study, the available mapping (and subsequently the backwater modeling) extended only a few thousand feet downstream from the Austin Avenue bridge.

Another significant difference between the modeling relates to the development of a specialized split flow analysis in the reach between the Fourth Street (Southside Drive) crossing and the vicinity of Stonebrook Court (located about 7,000 feet upstream from the Fourteenth Street (Custer Road) crossing. In this particular reach, the Willis Creek channel is somewhat "perched" in comparison to the left (north) overbank area. Only the most frequent flood events remain contained within the channel area through this reach. During passage of less frequent events, the overwhelming majority of the total discharge spills into the left overbank area, and is passed via city streets toward Fourth Street (Southside Drive). This topographic condition was handled in a fashion whereby the left overbank area was treated as the primary flow path in the backwater model. The total discharge-carrying capacity of the Willis Creek channel and its relatively high right (south) overbank was computed separately, and deducted from the total discharge applied to the left (north) overbank. Existing condition water surface profiles along Willis Creek are presented on Plate B-2.

Three economic damage centers were identified along Willis Creek. These include: a residential neighborhood situated on the right (south) overbank, adjacent to and downstream from Austin Avenue; a senior citizens home and multi-family apartments, situated adjacent to the Fourth Street (Southside Drive) crossing; and a residential neighborhood situated along the left (north) overbank split flow reach, which was discussed in the preceding paragraph. Scattered floodplain developments in the vicinity of the US Highway 377 crossing were also included in the economic analyses, but were found to clearly lack sufficient existing condition expected annual damages to justify any structural or non-structural solutions.

IMPROVED CONDITIONS

PECAN BAYOU

Initially investigated plans included a series of major channel modifications in the reach extending downstream from the concrete channel dam located about 290 feet upstream from the US Highway 67/377 crossing. However, it was determined that extensive excavation was required in order to significantly reduce flooding depths on the upstream side of the channel dam. Since computed benefits were essentially limited to those derived in relation to the relatively few commercial properties situated along the Pecan Bayou channel, adjacent to US Highway 67/377, this alternative was found to lack economic justification.

Consideration was next given to the potential for widening (lengthening the crest length of) the concrete channel dam, in combination with adjacent channel modifications. In this particular scenario, the dam would have been extended only in the northern direction, opposite from the existing city park along US Highway 67/377. This alternative was tested both as a "stand alone" solution and in combination with the previously mentioned channel modification plan(s). In both cases, these alternatives provided potential for significantly reducing flooding depths for only the relatively frequent flood events. Since the overwhelming majority of the existing damageable properties are situated at elevations well above the frequent event flood levels, these solutions were found to provide relatively minor reductions in the expected annual damages and to therefore lack economic justification.

At this point in the plan formulation process, the focus was shifted towards methods of enhancing conveyance in the split flow path along the Pecan Bayou Slough. Initial consideration was given to the idea of developing a channel modification generally along the center of the existing slough, from near its downstream confluence with the Pecan Bayou channel to the vicinity of Woodson Road. However, based on anticipation of requirements for significant environmental mitigation with this type of alternative, the proposed channel alignment was shifted northeastward, into the left overbank of the Pecan Bayou Slough. An almost linear alignment was developed that would "skirt" past the more northeastern meanders of the existing slough, and then uniformly merge with the slough on the northwest (upstream) side of Woodson Road. This alternative also required provisions for a bridge and/or culvert crossing on Woodson Road, at a point about 1,700 feet northeast from its existing bridge across the slough. A series of grass-lined, trapezoidal modifications with bottom widths ranging from 10 to 100 feet were evaluated in detail, but each was nonetheless found to lack economic justification.

WILLIS CREEK

Investigated plans included a series of grass-lined, trapezoidal channel modifications, economically optimized for flood damage reduction benefits in the lower damage reach, located adjacent to and downstream from Austin Avenue. Side slopes of 3H:1V were applied with bottom widths ranging from 10 to 125 feet. Initially, the reach proposed for improvement extended downstream to a point near the City of Brownwood's wastewater treatment plant. However, it was subsequently determined that overall project economics would be enhanced by truncating the project much further upstream, at a point approximately 4,900 feet downstream from the Austin Avenue bridge. Once an optimal configuration was determined for the lower damage reach, the process was then continued upstream, with the assumption that the lower reach of improvement would be "in place" with each of the subsequent alternatives in more upstream reaches. Once this process had been completed for all three primary damage reaches, it was noted that the preliminary, optimized array strongly supported the idea of applying a uniform trapezoidal channel bottom width throughout all three primary damage reaches. Results in the intervening reaches (i.e. those between the primary damage centers) did not provide an indication that channel modifications were necessary in those reaches, solely from an economic standpoint. However, it was deemed inappropriate, both from an engineering and political standpoint, to propose leaving those relatively short reaches of channel unimproved, while substantial channel modifications were being applied both upstream and downstream from those less-developed reaches. Beginning at this point in the plan formulation process, all investigated alternatives would have a constant trapezoidal channel bottom width, throughout the improved reach.

A series of bottom widths ranging up to 60 feet were evaluated in significant detail. The concurrent economic analyses indicated that excess annual project benefits (total annual benefits minus total annual costs) would be optimized with a 45-foot bottom width. This plan, which begins about 4,900 feet downstream from the Austin Avenue bridge and ends in the vicinity of Stonebrook Court, about 7,000 feet upstream from the Fourteenth Street (Custer Road) crossing, is generally aligned to avoid existing developments. Below Austin Avenue, the alignment shifts to the left (north), in an attempt to minimize construction impacts upon residential properties along Quail Run. Similarly in the reach in the vicinity of Fourteenth Street (Custer Road), the alignment shifts to the right (south), in an attempt to minimize construction impacts upon residential properties along Stonebrook Court, Asbury Street and Court, Stonegate Court, Stonecreek Circle, Shepherd Drive, Fourteenth Street (Custer Road) and Magnolia Street. Improved condition water surface profiles along Willis Creek are presented on Plate B-3.

The invert elevations along the improved reach were chosen in a manner to reasonably minimize excavation quantities and maintain existing bridge and/or culvert inverts. An overwhelming proportion of the total excavation results from widening, rather than deepening, of the Willis Creek channel. This alternative requires modification to the terrain beneath the Austin Avenue bridge, but is not anticipated to directly impact the bridge structure itself. It also necessitates the addition of box culverts to those already existing at the Fourth Street (Southside Drive) crossing and the replacement of the existing box culverts at the Fourteenth Street (Custer Road) crossing.

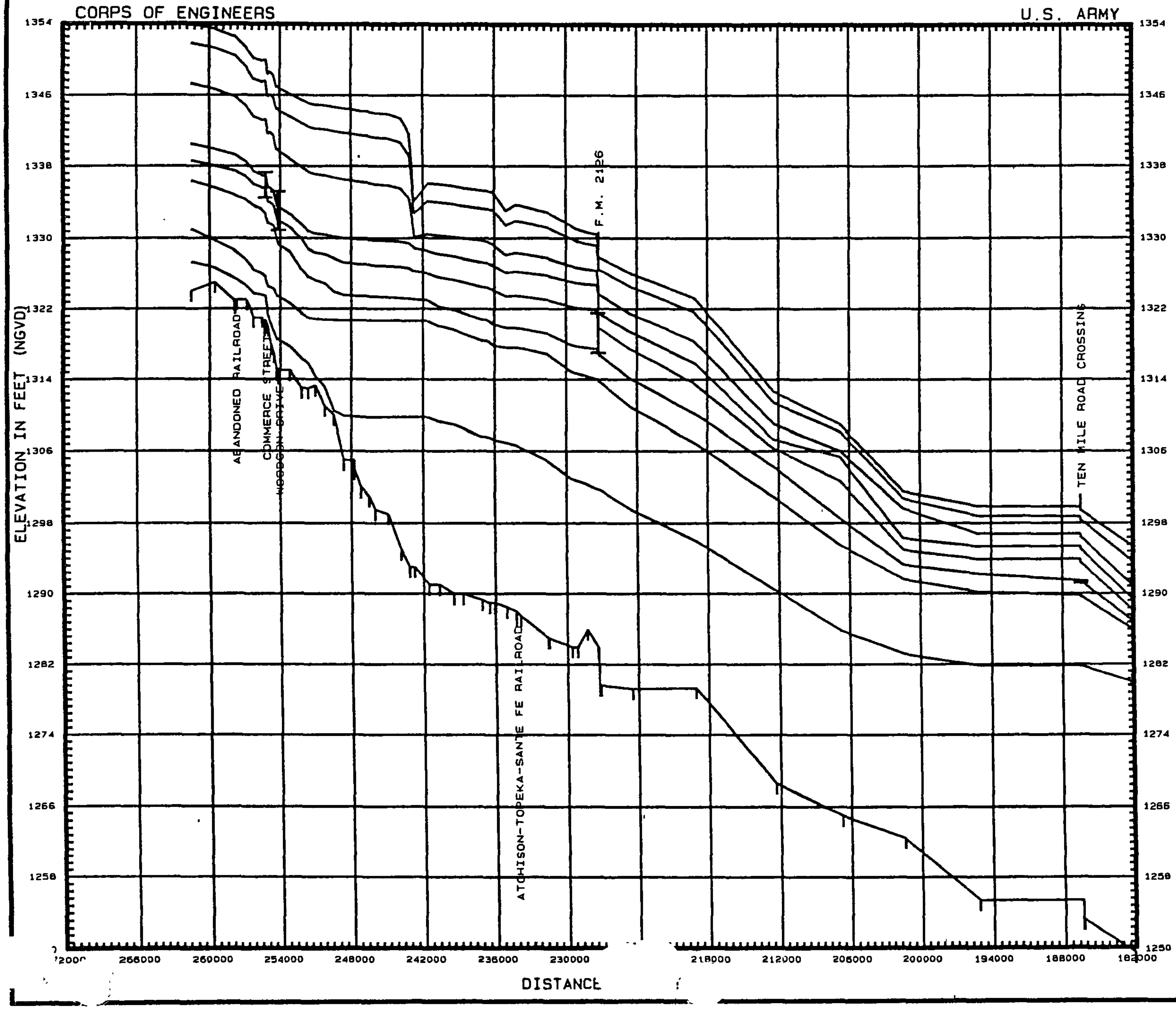
Late in the feasibility study, it was determined that the local sponsor would potentially have difficulties in properly maintaining the proposed 3H:1V side slopes. Therefore, a more flattened 3.5H:1V side slope was chosen, in combination with a more narrowed bottom width and a more widened top width, such that the effective channel size remained equivalent to that which had been used in the economic optimization. In this particular case, the bottom width was shifted from an original value of 45 feet, to a final value of 40 feet.

It was noted that opportunities existed for shifting the proposed channel alignment into the left (north) overbank in the reach immediately upstream from the Fourth Street (Southside Drive) crossing. This adjustment would provide for substantial reductions in habitat losses along that environmentally sensitive reach of the existing Willis Creek channel. The left (north) overbank paralleling this reach has been significantly impacted by human activity and does not exhibit a high quality of environmental resources.

Due to the relatively smooth alignment of the proposed channel, several existing channel bends would be at least partially severed by the project. In order to provide for continued passage of low flows through the original channel bends, shallow berms would be installed across the proposed trapezoidal channel base, immediately downstream of the upstream end of each severed bend. Addition provisions are included for the installation of a pilot channel along reaches of the improvement which are external to the severed bends. The pilot channels will be used both to enhance the environmental resources along the widened channel reaches and to direct the low flows into the severed channel bends.

SEDIMENTATION/DEGRADATION EVALUATION

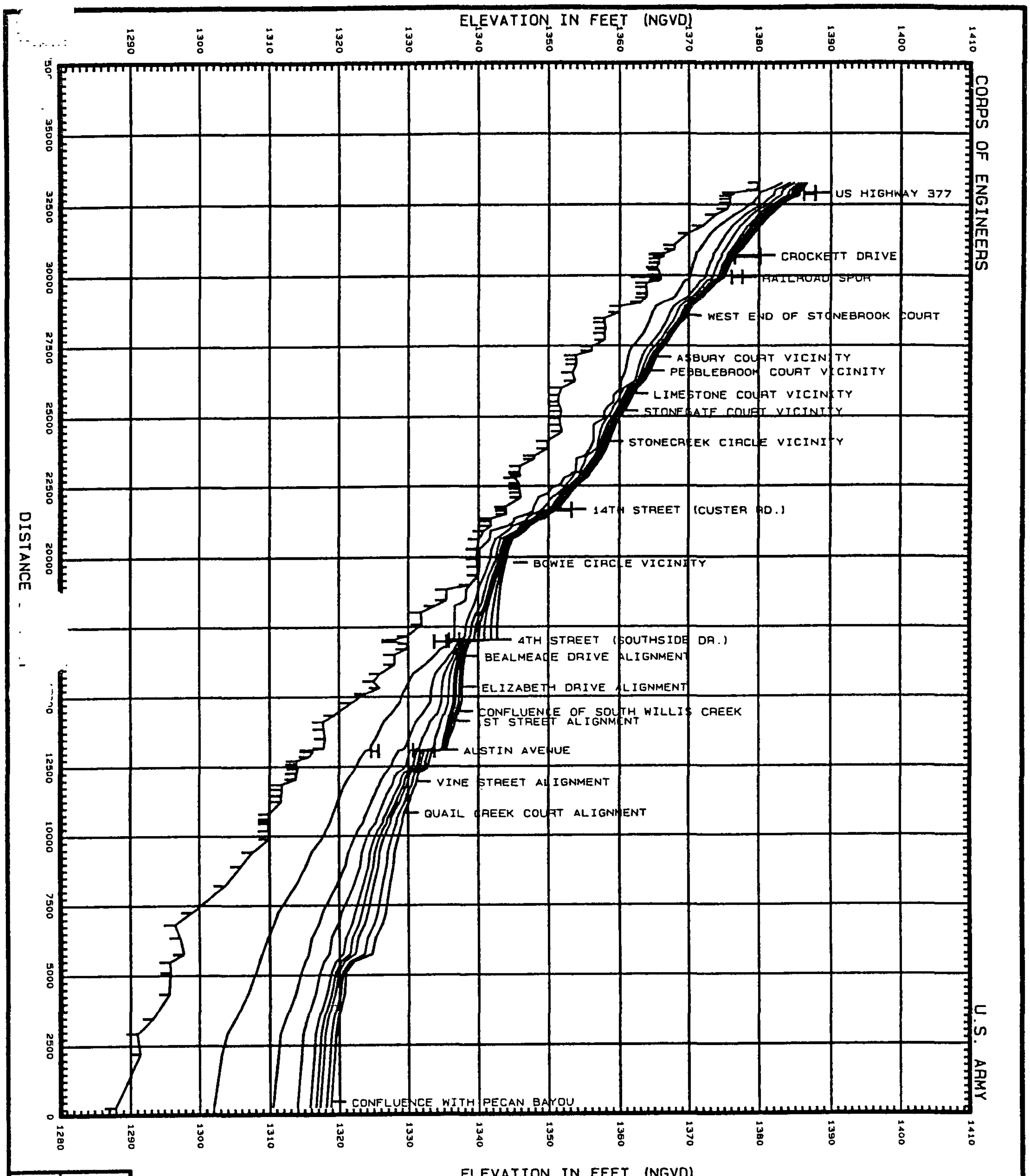
Under existing conditions, the Willis Creek channel appears to be stable and is experiencing neither significant sedimentation nor degradation. An evaluation of the change in channel flow velocities for the improved conditions indicates that although speeds would be increased in some locations, most of these increases are relatively small. The improved channel flow velocities should be within the range of acceptability for grass-lined modifications. Riprap-lining of the channel bottom and bank may be required in a few, selected locations. However, no conditions are anticipated which would significantly affect economic justification of these projects.



PECAN BAYOU
BROWNWOOD, TEXAS
2-, 5-, 10-, 25-, 50-, 100-, 500- &
1000-YEAR FREQ. FLOOD EVENTS
UNDER EXISTING CONDITIONS

U.S ER DISTRICT, FORT WORTH

PI B-1



WILLIS CREEK
BROWNWOOD, TEXAS
2-, 5-, 10-, 25-, 50-, 100-, 250-, &
500-YEAR FREQUENCY FLOOD EVENT
EXISTING CONDITIONS

U.S
A DISTRICT, FORT WORTH

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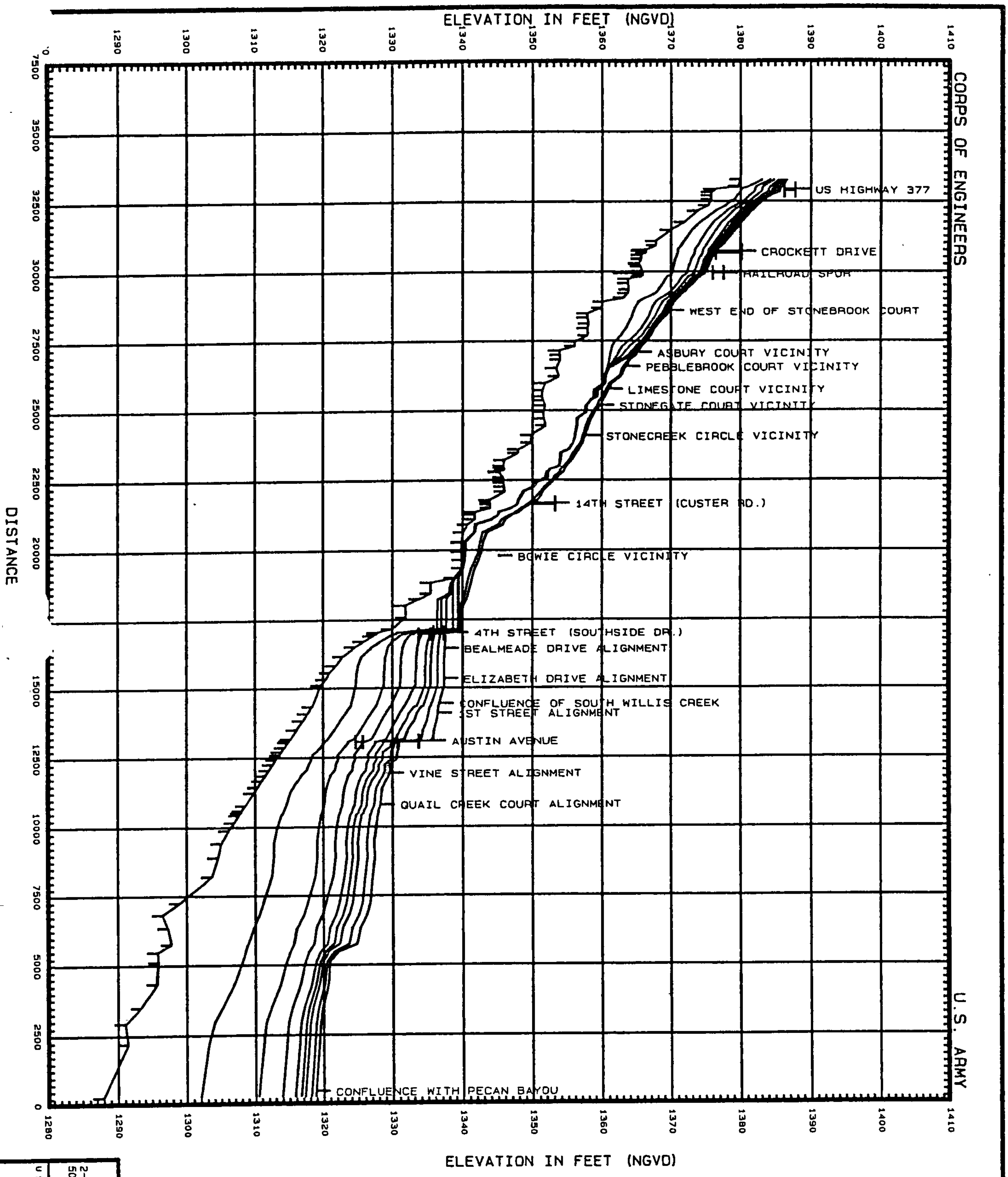


WILLIS CREEK
BROWNWOOD, TEXAS
2-, 5-, 10-, 25-, 50-, 100-, 250-,
500-YEAR FREQUENCY FLOOD EVENT
WITH NED CHANNEL PLAN

U S
EA DISTRICT, FORT WORTH

LA -3

SUB-APPENDIX C

CIVIL DESIGN

CIVIL DESIGN and RELOCATIONS

CHANNEL IMPROVEMENT

The selected plan consists of improving 15,680 feet of Willis Creek within the city of Brownwood. The plan of improvement shall consist of a grass-lined trapezoidal channel. The realigned channel would have 1V:3.5H side slopes with a bottom width of 40 feet. The depth will vary between 4 and 11 feet with the top width varying from 40 to 135 feet. The improvement will begin at STA 10+00, which is at the existing creek about 200 feet to the south from the west end of Stonebrook Court. The downstream end will be located about 1600 feet east of Quail Creek Court. The alignment of the improvement primarily follows the existing creek, except for several oxbows that are avoided and surpassed; then rejoins the existing creek just downstream of the oxbows. At STA 78+00, which is 1140 feet downstream of 14th St (F.M. 3064), the alignment diverts from the existing creek and "straight-lines" to the intersection of Willis Creek and 4th Street, which is STA 100+00. Environmental mitigation is the reason for this diversion.

DISPOSAL

The City of Brownwood has established a location for the excess excavated and waste materials. The primary site for the disposal of materials from Willis Creek is the Brownwood City landfill located about 0.75 miles southwest of the intersection of F.M. 2126 and F.M. 45. The haul distance from Willis Creek to the landfill will vary from 3-5 miles.

RELOCATIONS

Structures Relocation or removal of small sheds and detached buildings that are within the limits of improvement, shall be the responsibility of the City at their expense prior to award of the Willis Creek Project.

Roads At STA 66+50 the improved alignment crosses Custer Road just south of Magnolia Street, 4th Street at STA 100+00, and Austin Avenue at STA 127+20. The Custer Road and 4th Street culverts will require a structural modification, but the Austin Avenue bridge will have sufficient capacity "as-is".

Utilities: Various utility lines will be impacted throughout the improvement along Willis Creek. The types of relocations will be extending utility lines to reach the improvement, rerouting lines below the newly excavated channel, or rerouting lines to horizontally circumvent the improvement.

UTILITY EXTENSIONS

Location	Station	Size and Type of Pipe	Pipe Material	Action Item
Asbury St	27+80	30-in Storm Drain (S.D.)	Reinforced Conc. (RCP)	Extended 115 ft
Stone Gate Ct	39+50	18-in S.D.	Galvanized Steel	Extended 160 ft
Good Shepard Dr	50+20	24-in S.D.	Corrugated Metal (CMP)	Extended 60 ft
Good Shepard Dr	55+00	48-in S.D	RCP	Extended 145 ft
Good Shepard Dr	56+20	48-in S.D	Galvanized Steel	Extended 85 ft

Utilities Crossing Below Channel:

Location	Station	Size and Type of Pipe	Pipe Material	Action Item

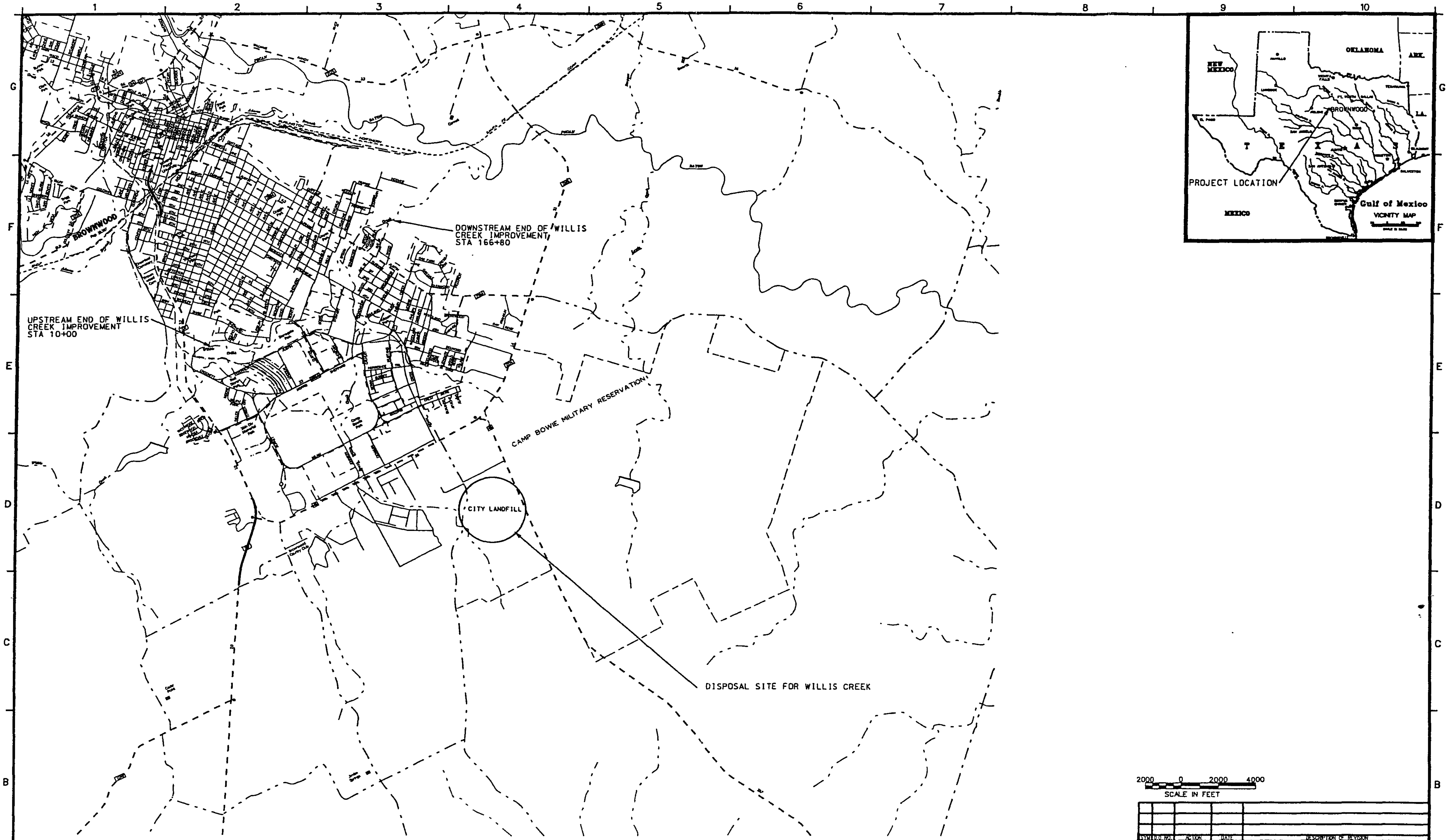
Southwest of 4th	96+00	12-in Sanitary Sewer (SS)	RCP	Rerouted 150 ft
4th Street	100+00	4-in Gas Line		Rerouted 115 ft
4th Street	100+10	10-in Water Line	Cement-Lined	Rerouted 130 ft
Austin Ave	127+00	6-in Water Line	Cement-Lined	Rerouted 145 ft
Austin Ave	127+50	18-in SS		Rerouted 141 ft
Vine St.	138+00	16-in Water Line	Cement-Lined	Rerouted 140 ft
Quail Run	141+00	18-in SS	PVC	Rerouted 150 ft

Utility Circumventing Channel:

Location	Station	Size and Type of Pipe	Pipe Material	Action Item
Quail Run	136+00	10-in SS	PVC	Horizontally Rerouted 900 ft

Overhead Utility:

Location	Station	Type of Utility	Material	Action Item
Quail Creek Ct	147+50	Electrical Powerline		



SYMBOL	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS

WILLIS CREEK
CHANNEL IMPROVEMENT

PROJECT LOCATION MAP

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO

DATED:

CONTR. NO

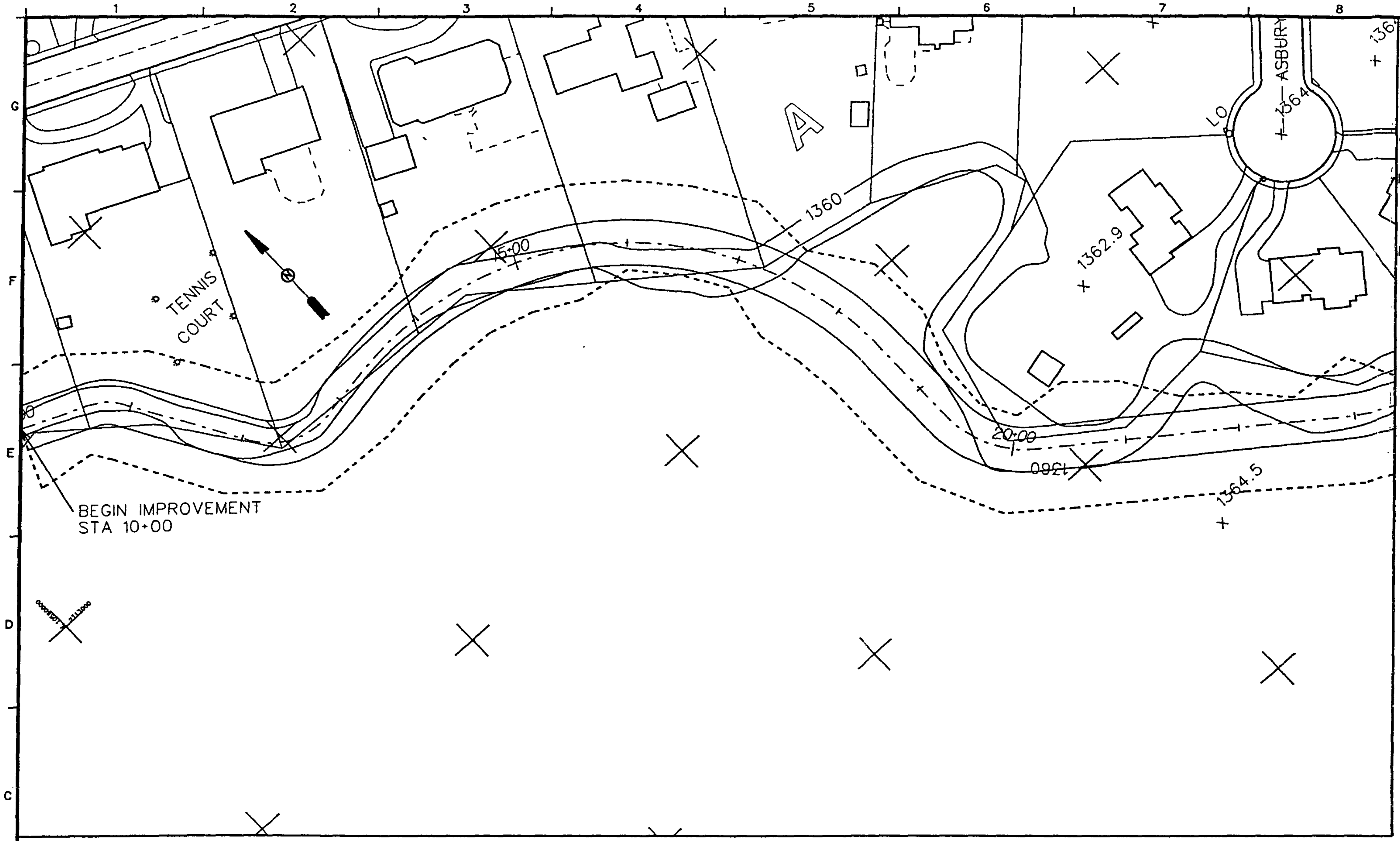
DRAWING NUMBER

SHEET NO.
OF

SEQUENCE NO.
1

CONTR. NO.

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION



PLAN

LEGEND

CENTERLINE OF IMPROVEMENT —·—·|—·—

PERMANENT EASEMENT
(LIMIT OF IMPROVEMENT) - - - - - - -

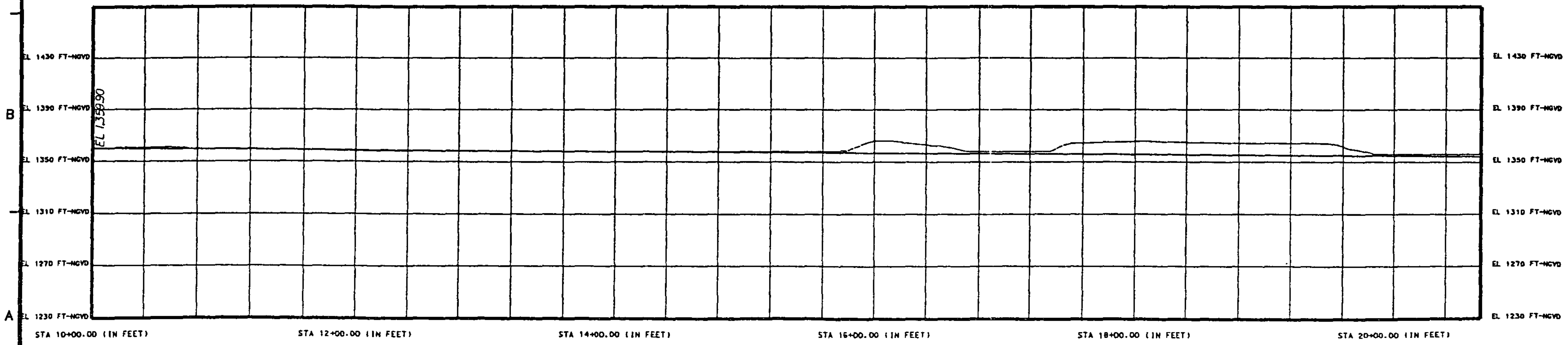
IMPROVED CHANNEL PROFILE ———

EXISTING GROUNDLINE PROFILE ·········

EXISTING MAJOR CONTOUR ~1350~

NOTES:

PLAN & PROFILE SHEETS ORIGINALLY CREATED AT A SCALE OF 1" = 40'. DRAWINGS HAVE BEEN REDUCED TO AN APPROX. SCALE OF 1" = 105'. DISTANCE BETWEEN COORDINATE TICK MARKS ON PLAN IS 250'.



CENTERLINE PROFILE

REFERENCE FILE NAME | REFERENCE FILE DESCRIPTION

SYMBOL D.O. NO. | ACTION | DATE | DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 10+00 TO 20+50

SUBMITTED BY:

TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
OF
SEQUENCE NO.
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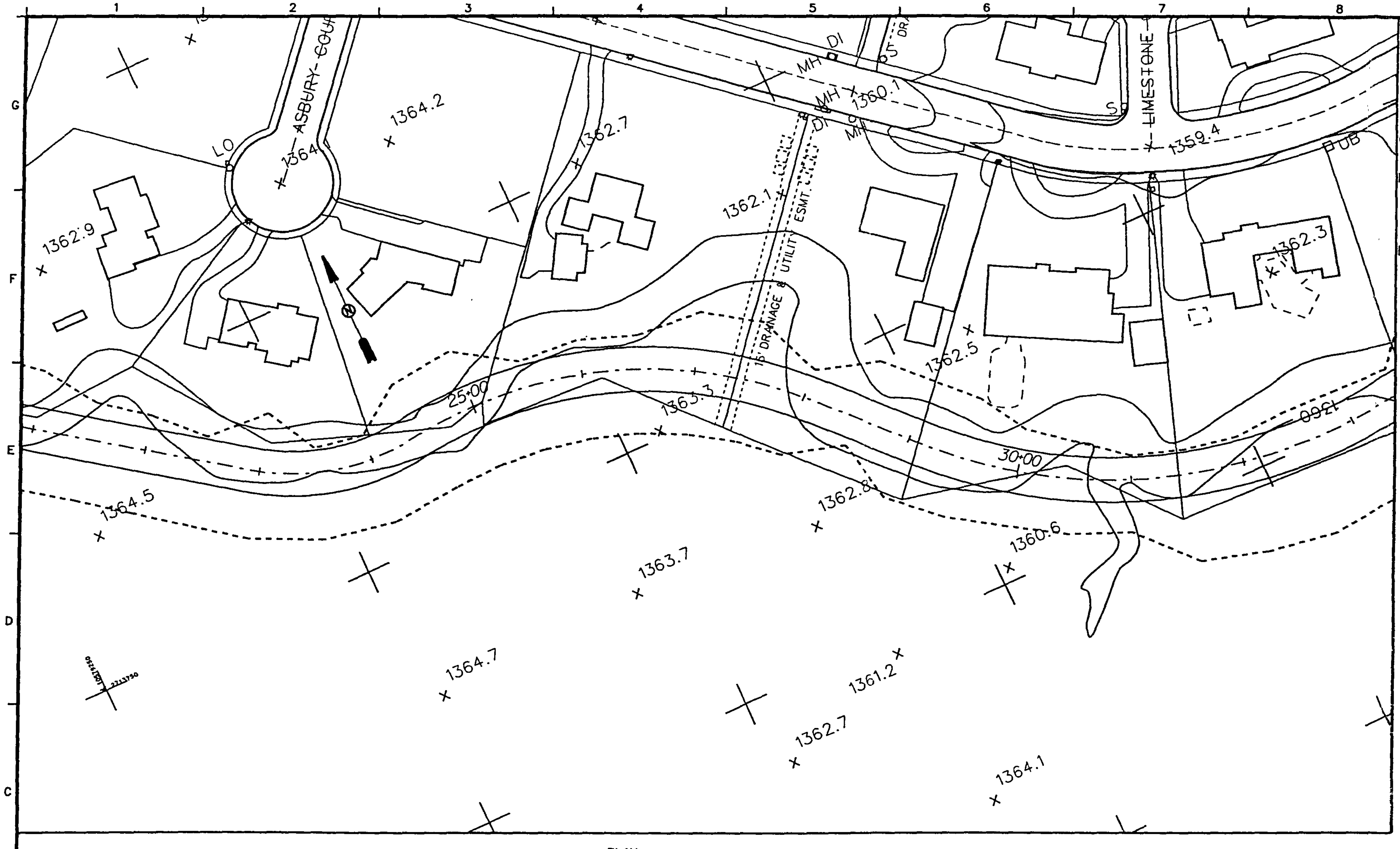

PLAN

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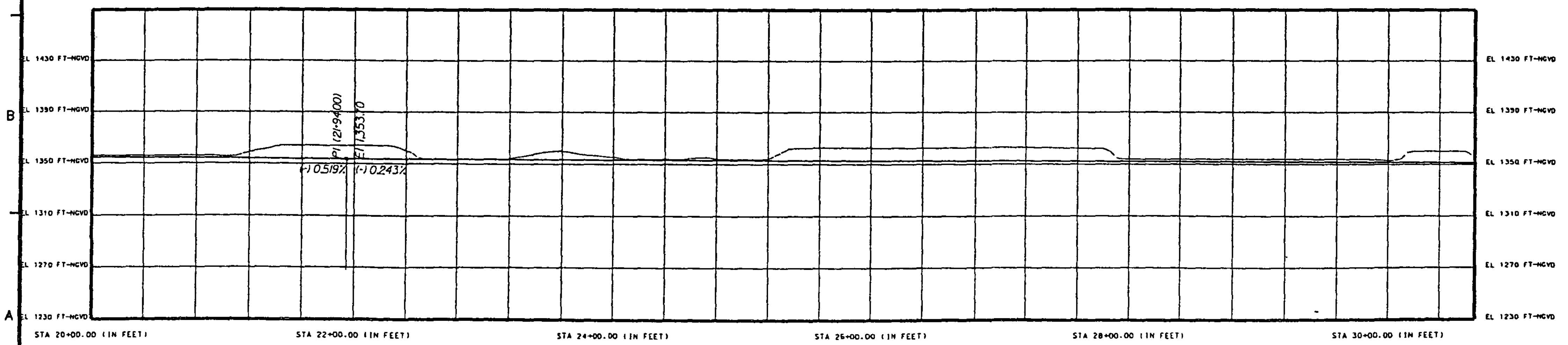
CENTERLINE OF IMPROVEMENT	— · — ı — · —
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)	- - - - - - -
IMPROVED CHANNEL PROFILE	———
EXISTING GROUNDLINE PROFILE	· · · · · · ·
EXISTING MAJOR CONTOUR	~ 1350 ~



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SYMBOL	DOC. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 20+50 TO 31+00

SUBMITTED BY:
TERRIL NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO
DATED:
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SHEET NO. OF
SEQUENCE NO. 3
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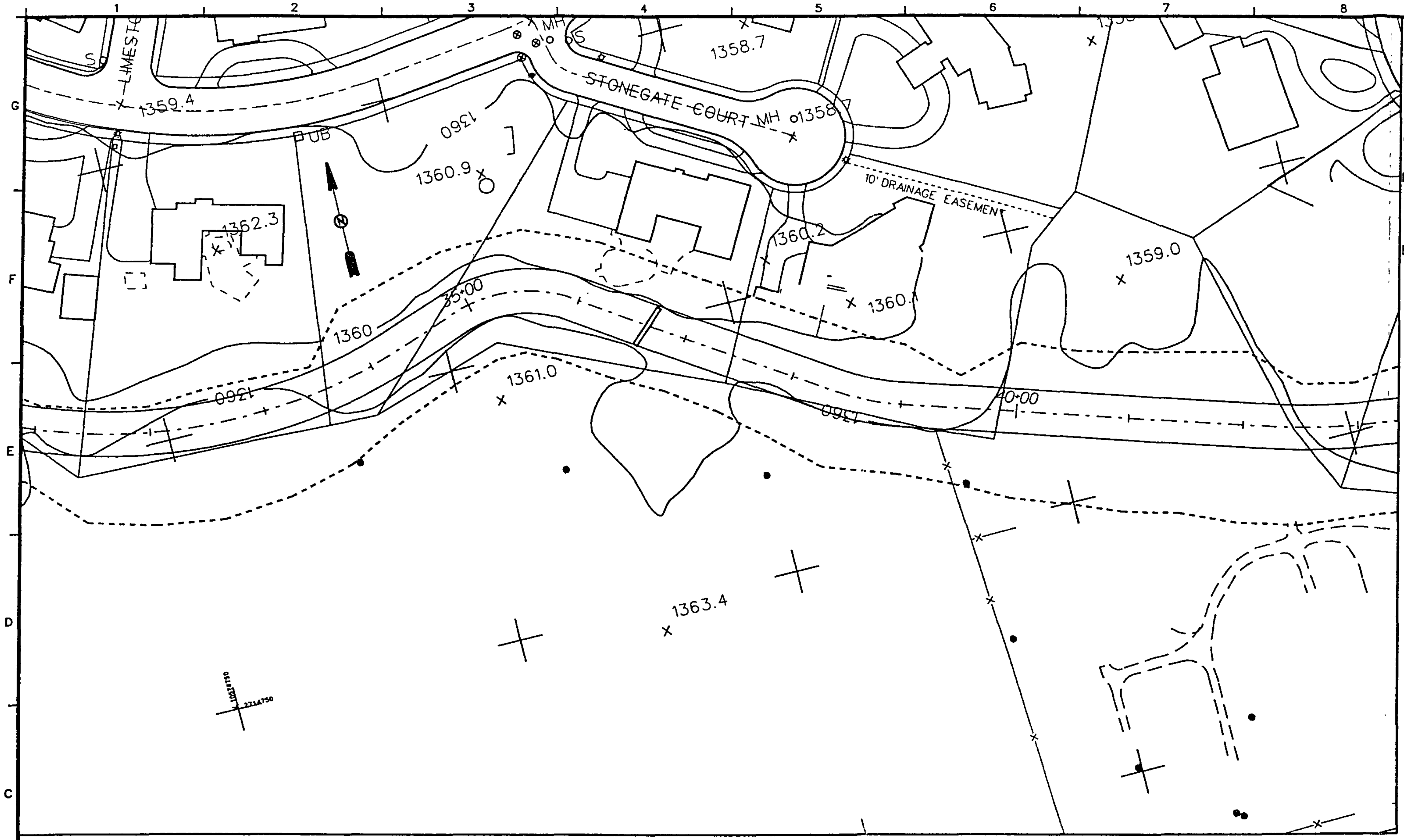
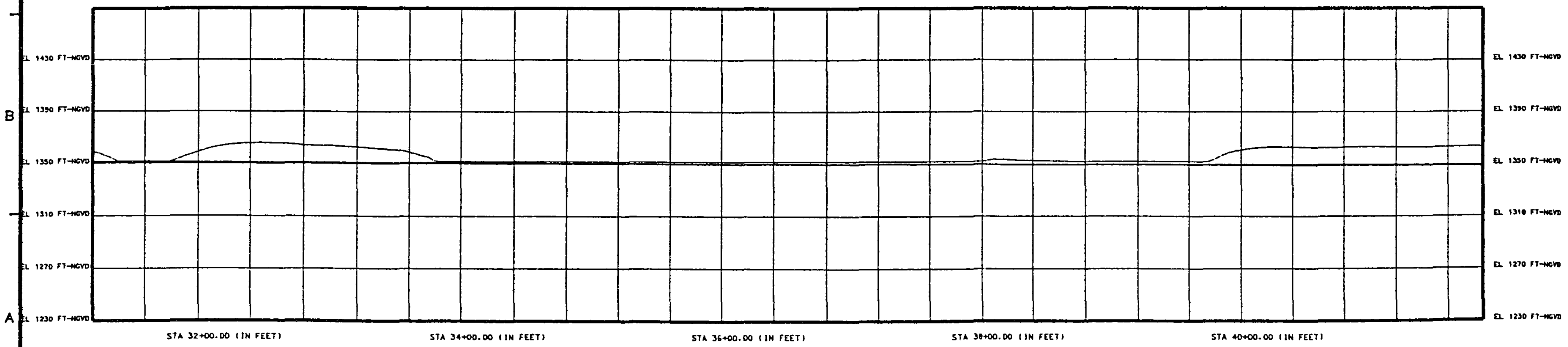


PLAN

LEGEND

- CENTERLINE OF IMPROVEMENT
- PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)
- IMPROVED CHANNEL PROFILE
- EXISTING GROUNDLINE PROFILE
- EXISTING MAJOR CONTOUR 1350



CENTERLINE PROFILE

SYM	U.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:
DRAWN BY:
REVIEWED BY:

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 31+00 TO 42+00

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

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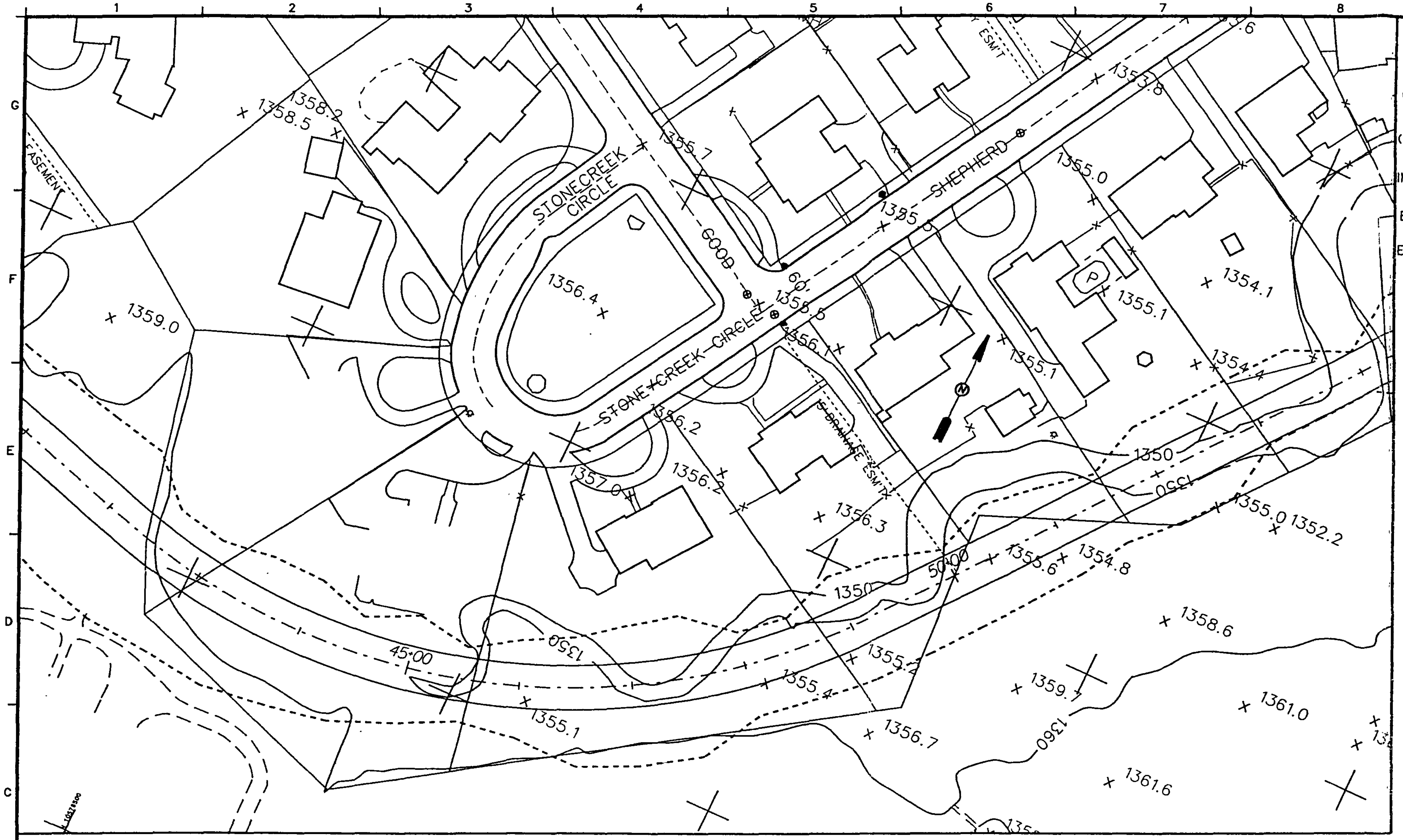

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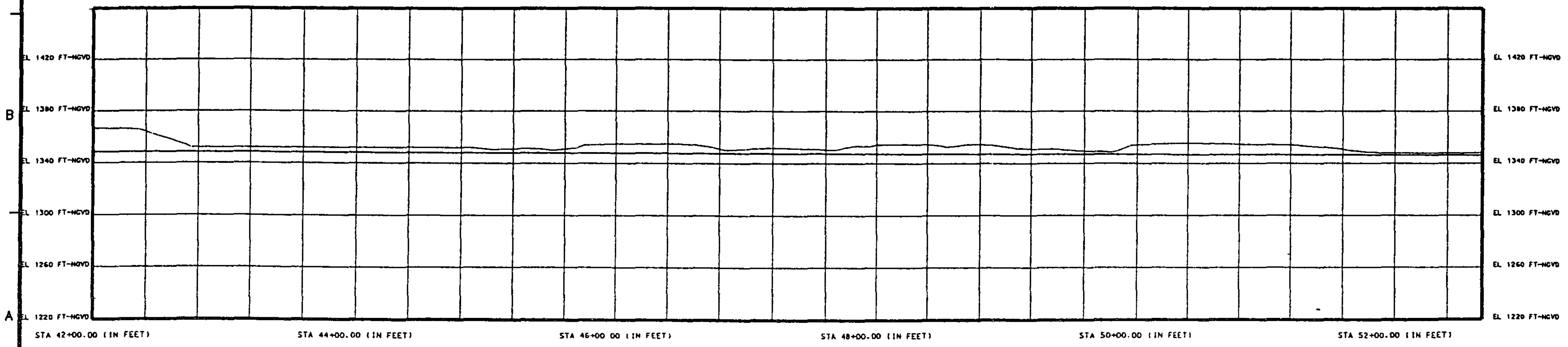
CENTERLINE OF IMPROVEMENT	— - — -|— - —
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)	- - - - - - - -
IMPROVED CHANNEL PROFILE	———————
EXISTING GROUNDLINE PROFILE	....
EXISTING MAJOR CONTOUR	~ 1350 ~

PLAN



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ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:
L. MENDOZA

DRAWN BY:
L. MENDOZA

REVIEWED BY:
E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 42+00 TO 52+50

SUBMITTED BY:
TERRIL L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
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DRAWING NUMBER
SHEET NO.
OF
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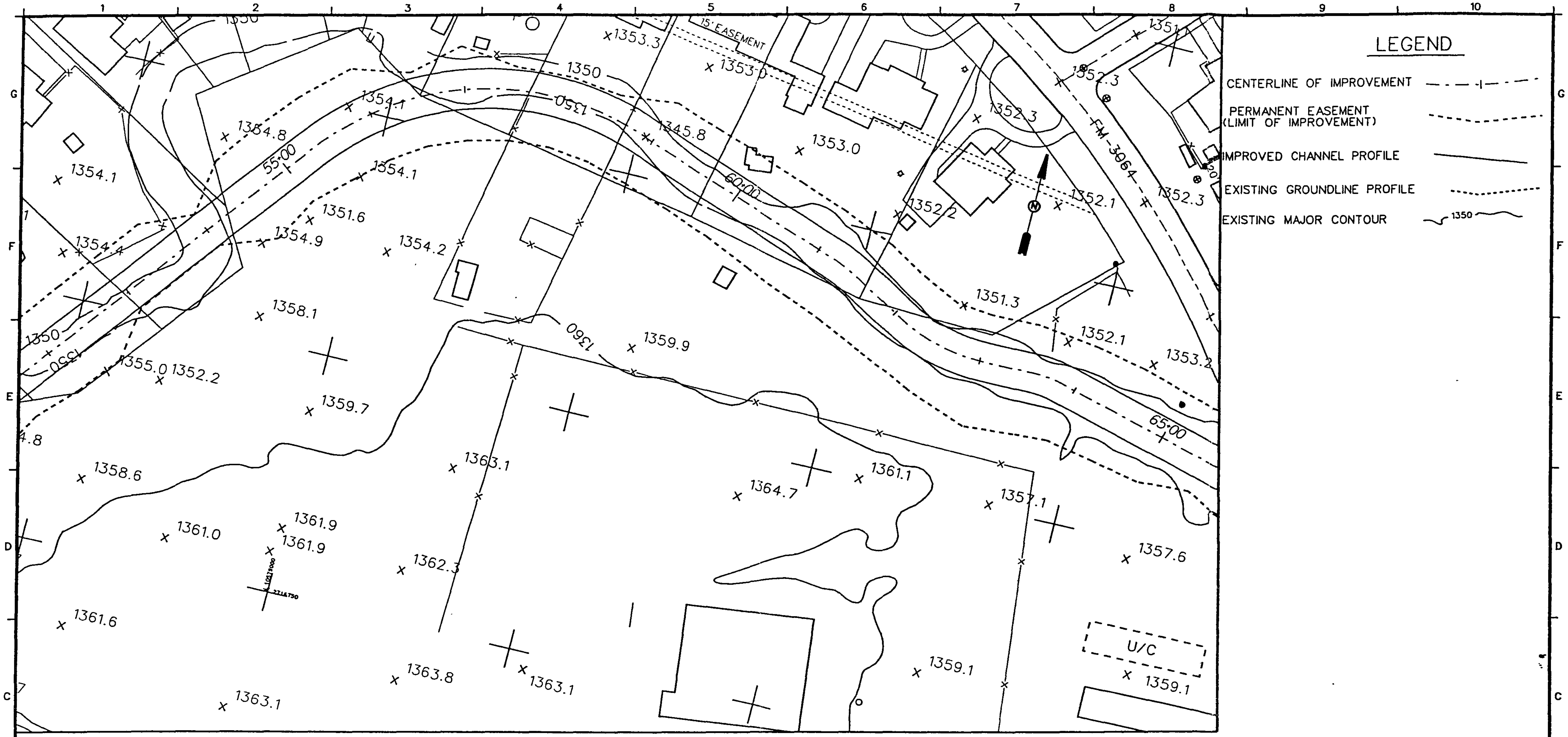
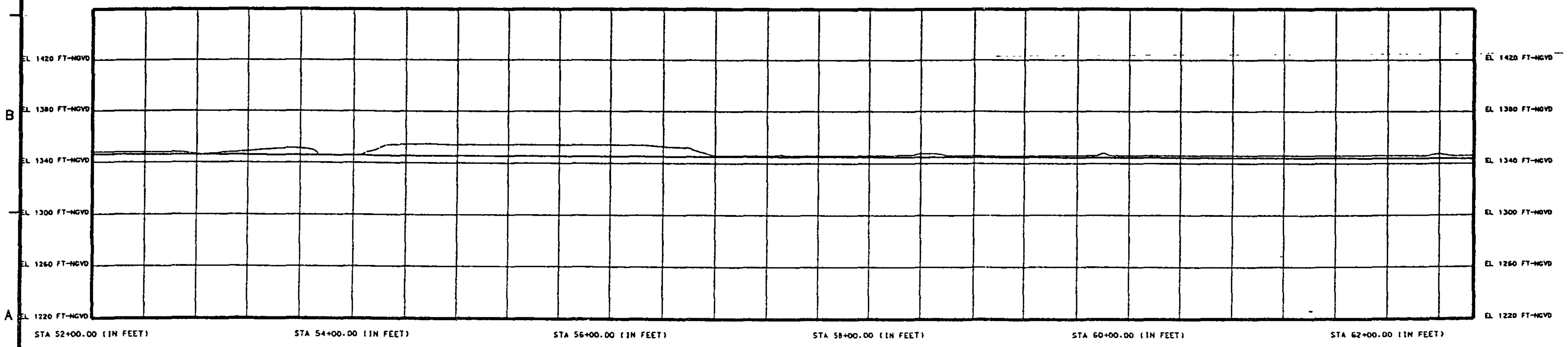
CADD FILE NAME: CPCP4 DGN



PLAN



CENTERLINE PROFILE

SYM	U.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

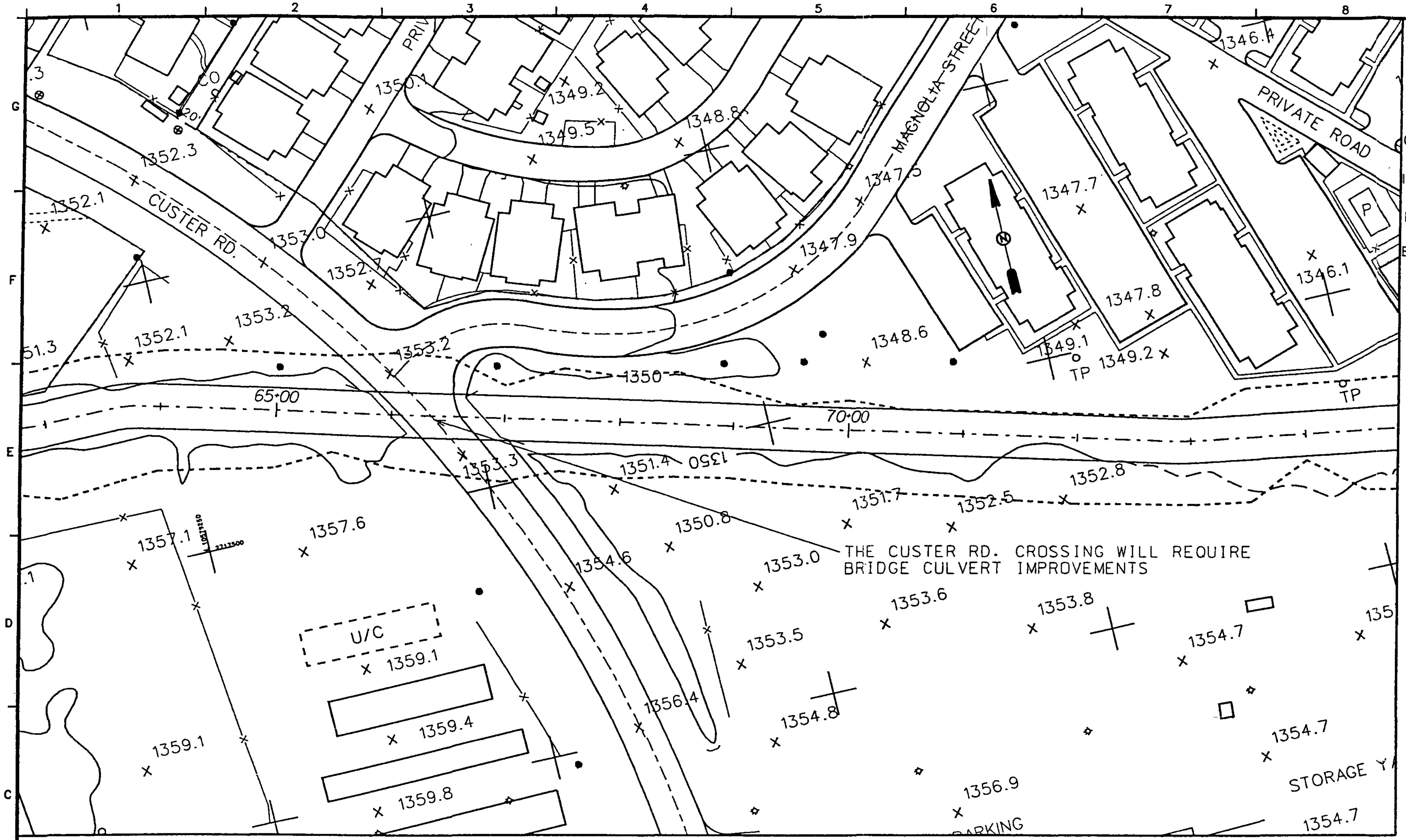
PLAN AND PROFILE
STA 52+50 TO 63+00

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 6
CONTR. NO.

REFERENCE FILE NAME
REFERENCE FILE DESCRIPTION

CADD FILE NAME: CPCP5.DGN



LEGEND

CENTERLINE OF IMPROVEMENT —·—|—·—

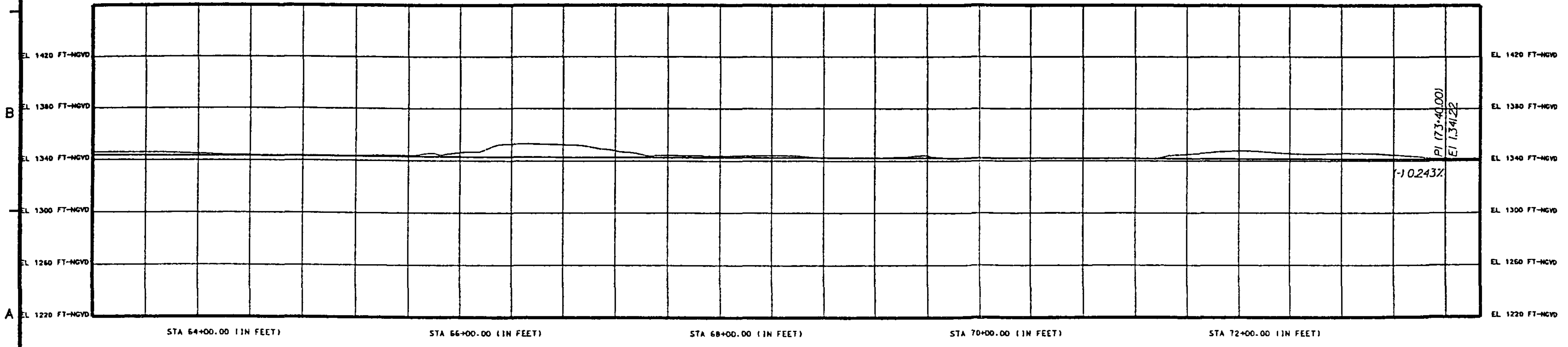
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT) - - - - - -

IMPROVED CHANNEL PROFILE ————

EXISTING GROUNDLINE PROFILE ··········

EXISTING MAJOR CONTOUR ~1350~

PLAN



CENTERLINE PROFILE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

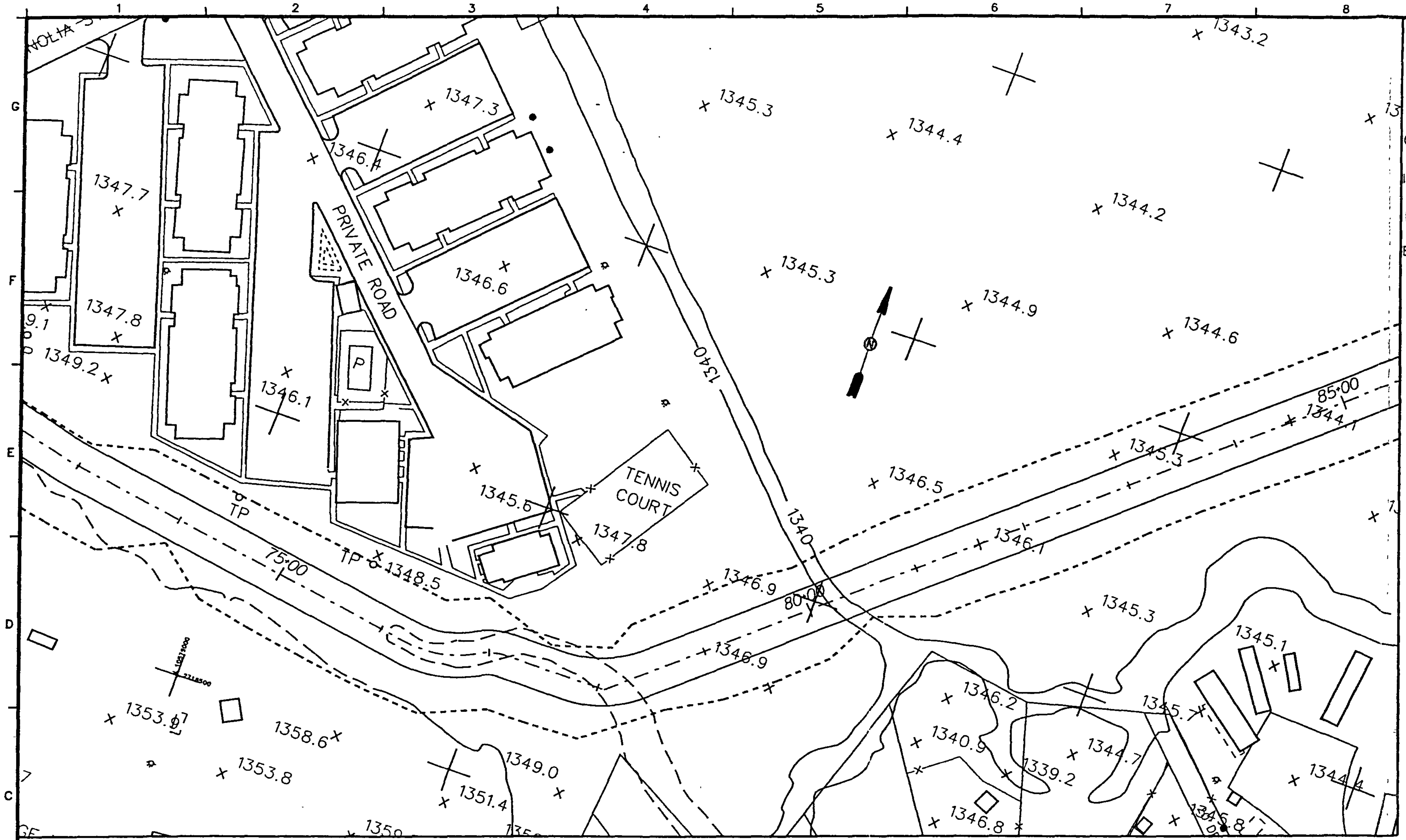
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 63+00 TO 74+00

SUBMITTED BY: TERRILL NOLEN P.E.
SOL. NO
DATED:
CONTR. NO.
SEQUENCE NO



PLAN

LEGEND

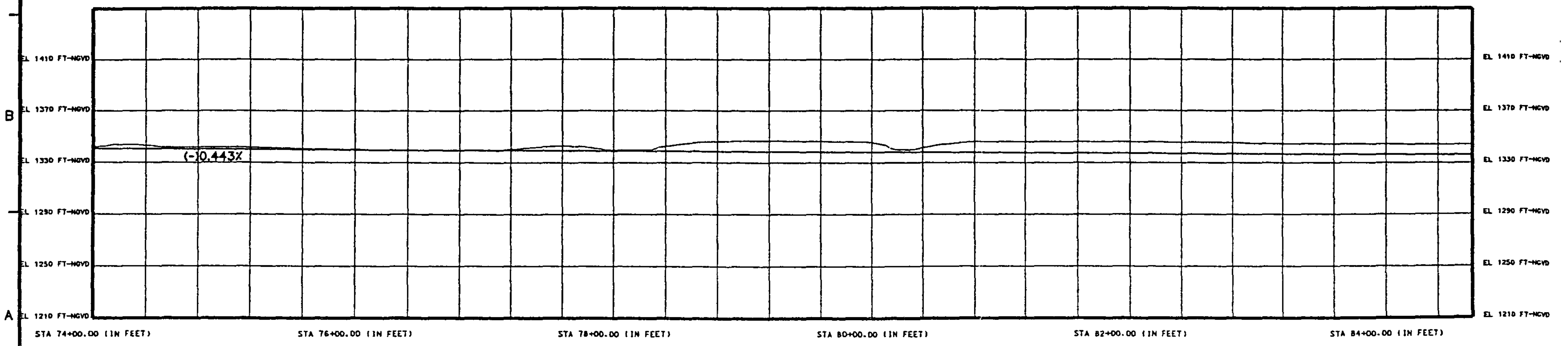
CENTERLINE OF IMPROVEMENT

PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)

IMPROVED CHANNEL PROFILE

EXISTING GROUNDLINE PROFILE

EXISTING MAJOR CONTOUR



CENTERLINE PROFILE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

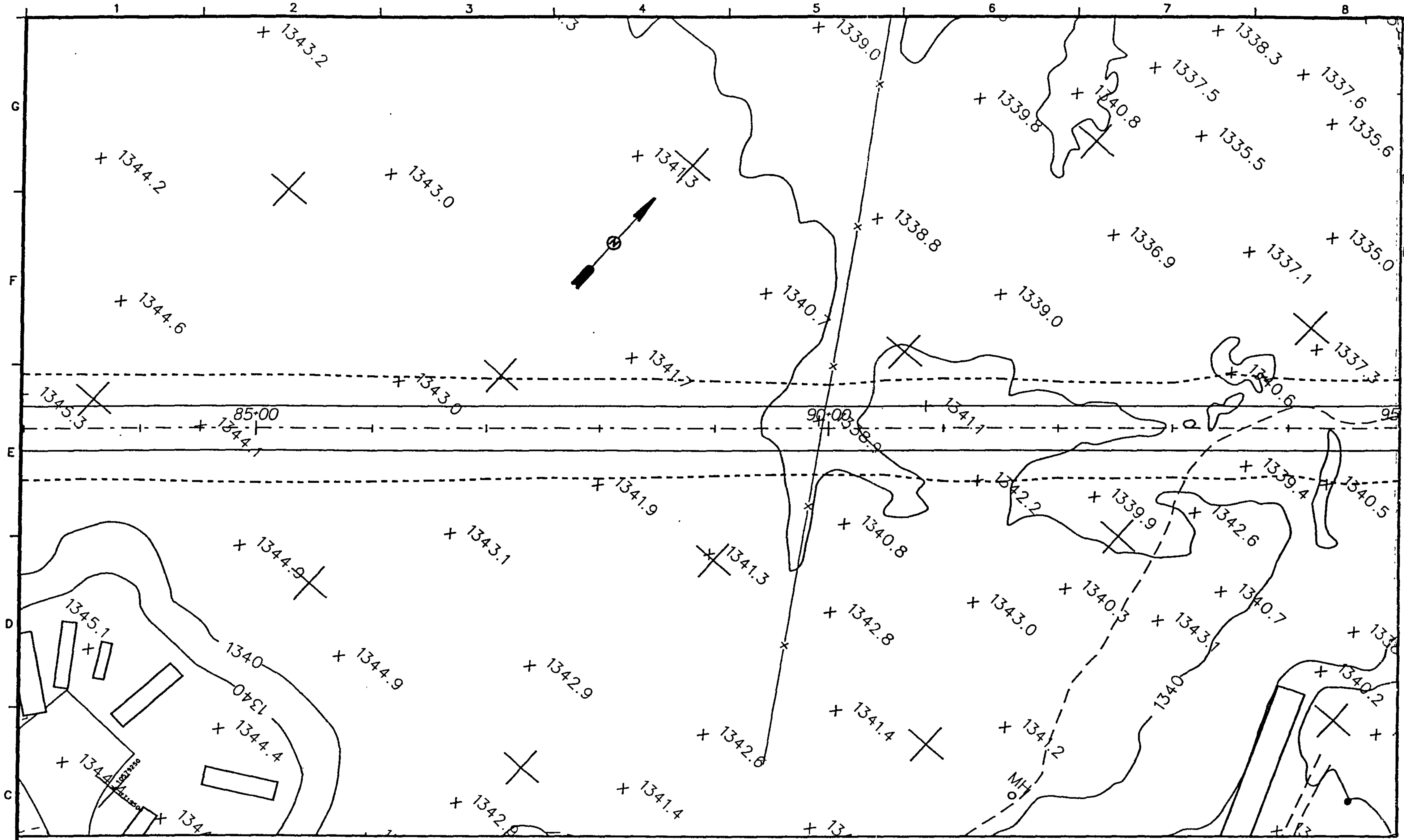
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 74+00 TO 84+50

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

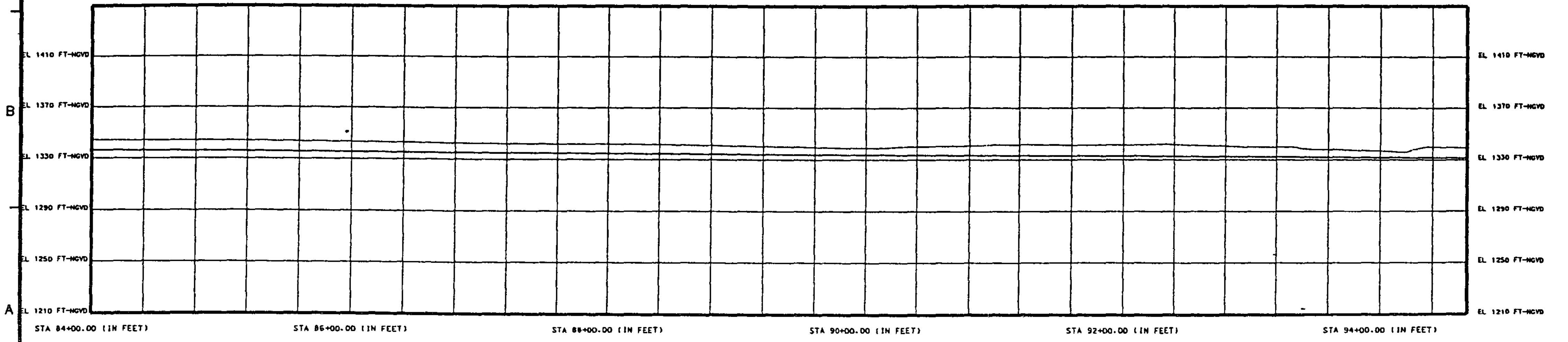
SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
SEQUENCE NO. 8
NTR NO.



PLAN

LEGEND

CENTERLINE OF IMPROVEMENT	— · — ·+· — · —
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)	- - - - - - - -
IMPROVED CHANNEL PROFILE	———
EXISTING GROUNDLINE PROFILE	··········
EXISTING MAJOR CONTOUR	~1350~



CENTERLINE PROFILE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

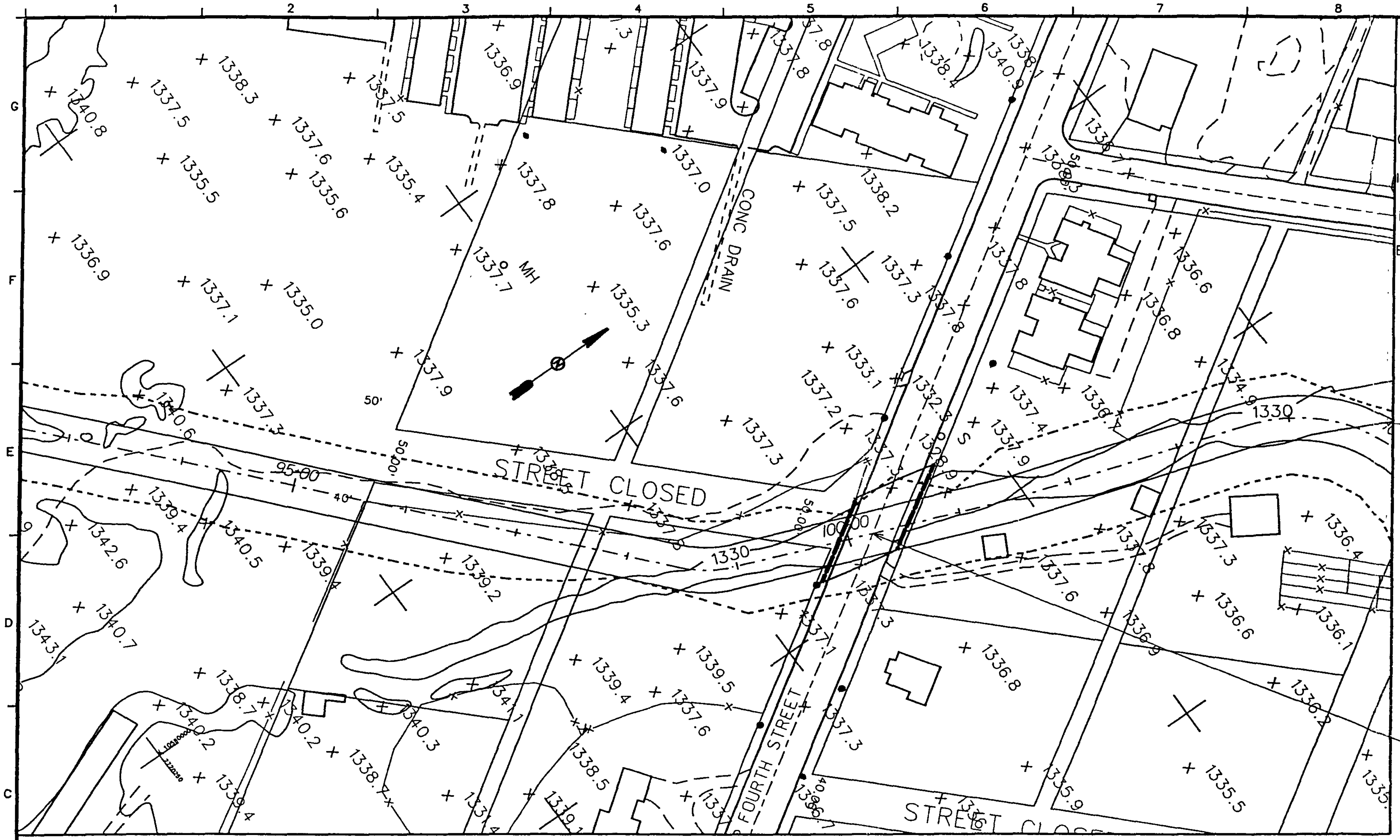
PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 84+50 TO 94+50

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 9
CONTR NO

CADD FILE NAME: CPCP8.DGN

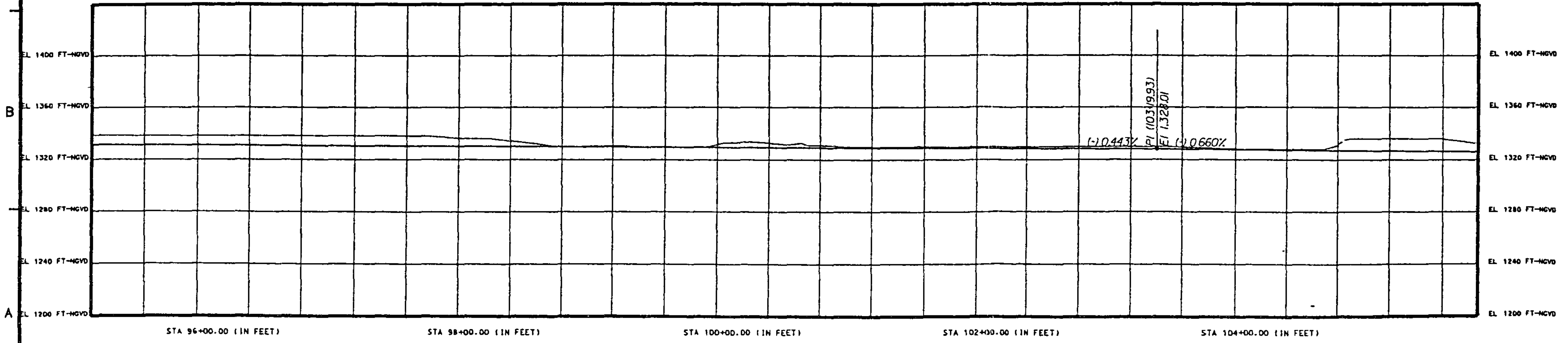


THE FOURTH ST. CROSSING WILL REQUIRE BRIDGE CULVERT IMPROVEMENTS

LEGEND

CENTERLINE OF IMPROVEMENT
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)
IMPROVED CHANNEL PROFILE
EXISTING GROUNDLINE PROFILE
EXISTING MAJOR CONTOUR 1350

PLAN



CENTERLINE PROFILE

SYMBOL NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 94+50 TO 106+00

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 10
CONTR. NO.

REFERENCE FILE NAME
REFERENCE FILE DESCRIPTION

LEGEND

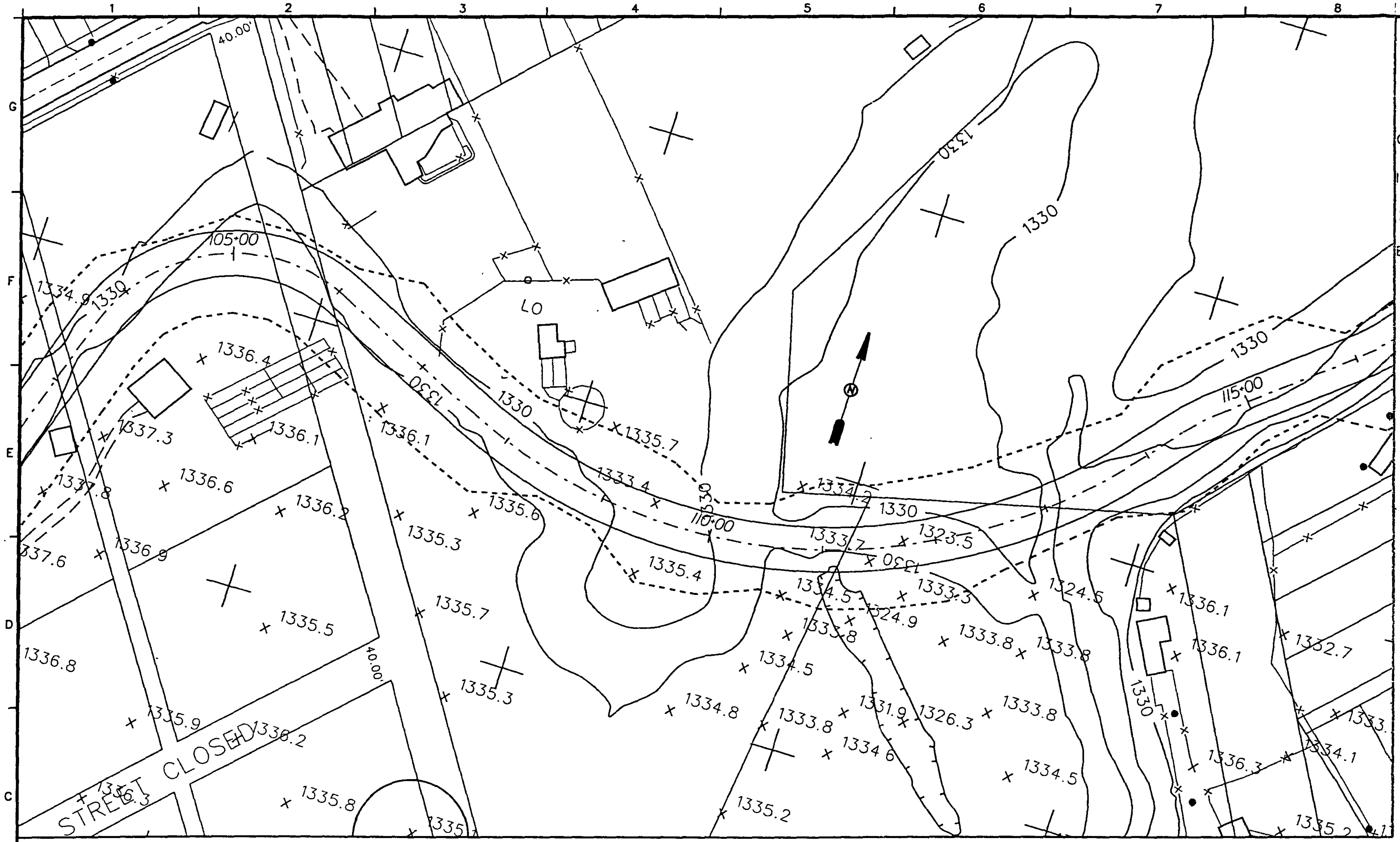
CENTERLINE OF IMPROVEMENT — · — ·|— · —

PERMANENT EASEMENT (LIMIT OF IMPROVEMENT) - - - - - - -

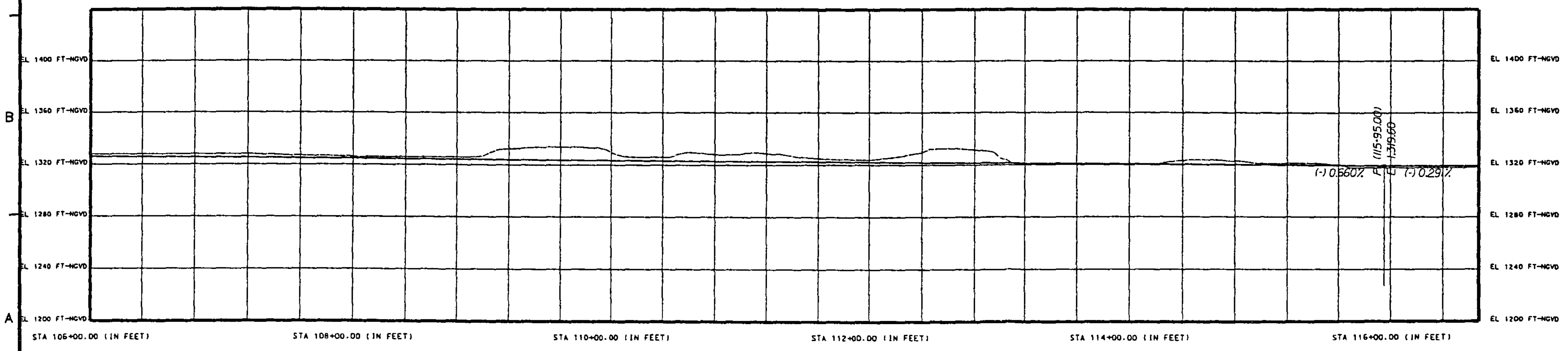
IMPROVED CHANNEL PROFILE ———

EXISTING GROUNDLINE PROFILE · · · · · · · ·

EXISTING MAJOR CONTOUR ~1350~



PLAN



CENTERLINE PROFILE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

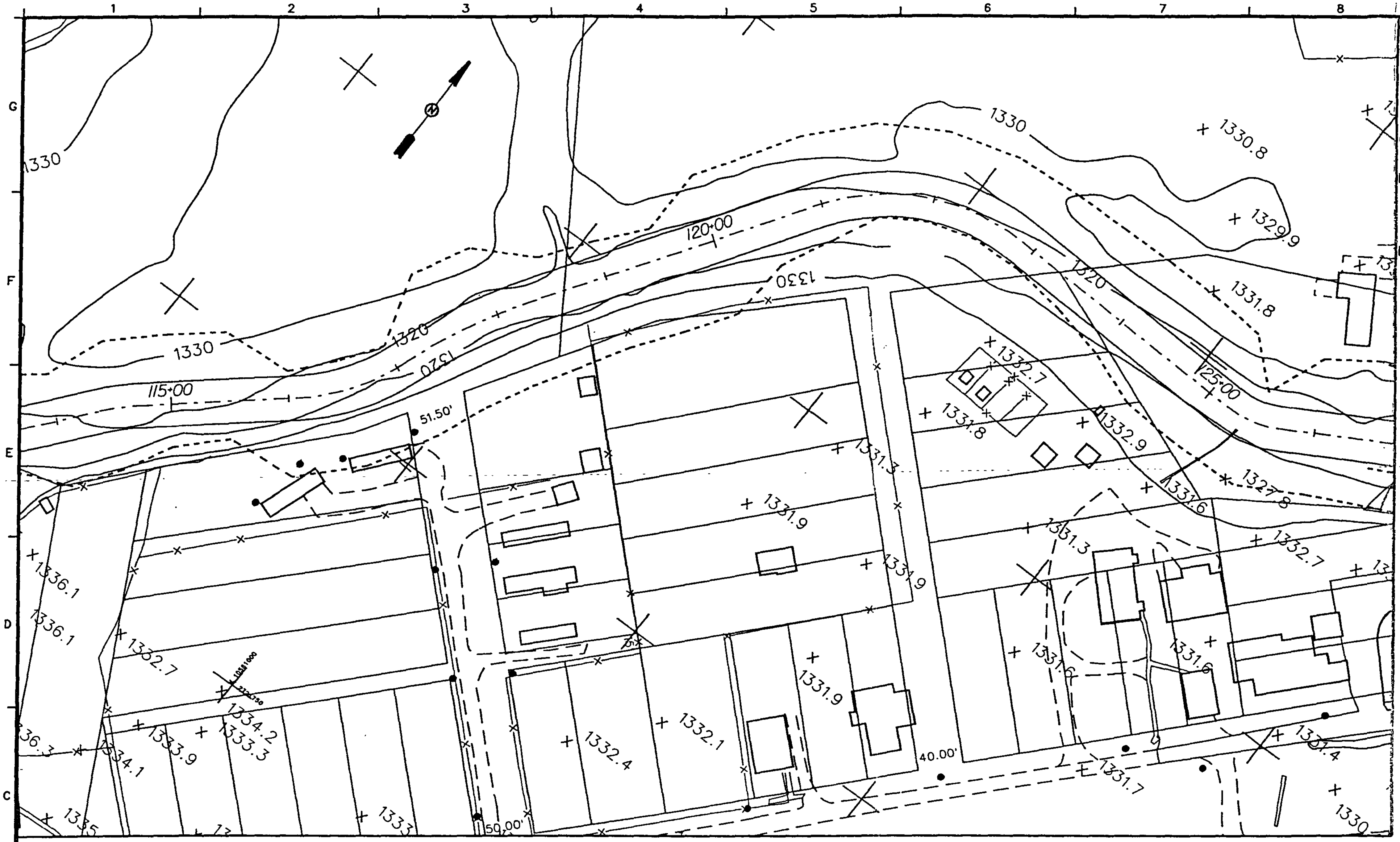
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

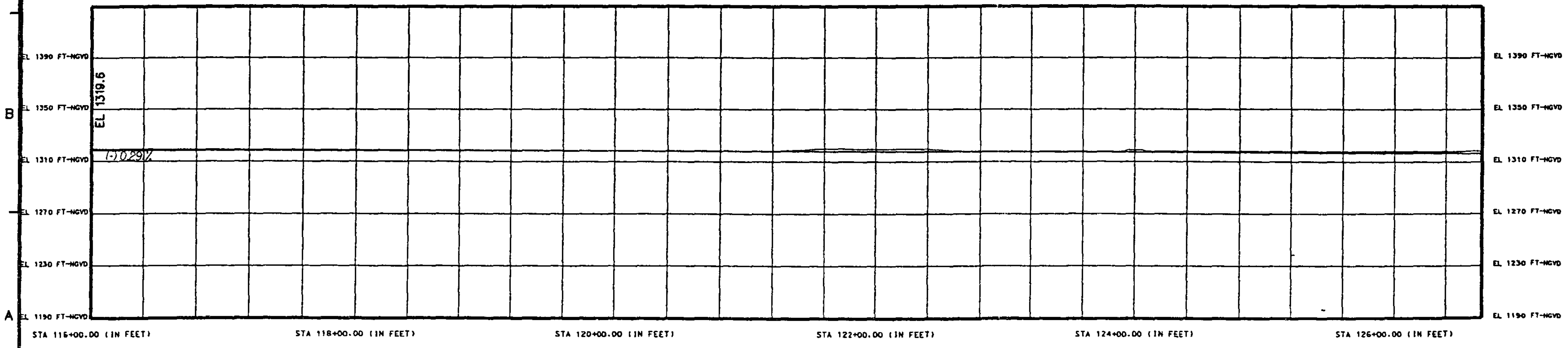
PLAN AND PROFILE
STA 106+00 TO 116+00

SUBMITTED BY:
TERRIL NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL NO
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO
SEQUENCE NO.
IR NO.



PLAN



CENTERLINE PROFILE

LEGEND

CENTERLINE OF IMPROVEMENT
PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)
IMPROVED CHANNEL PROFILE
EXISTING GROUNDLINE PROFILE
EXISTING MAJOR CONTOUR 1350

REFERENCE FILE NAME
REFERENCE FILE DESCRIPTION

SYMBOL	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

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DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

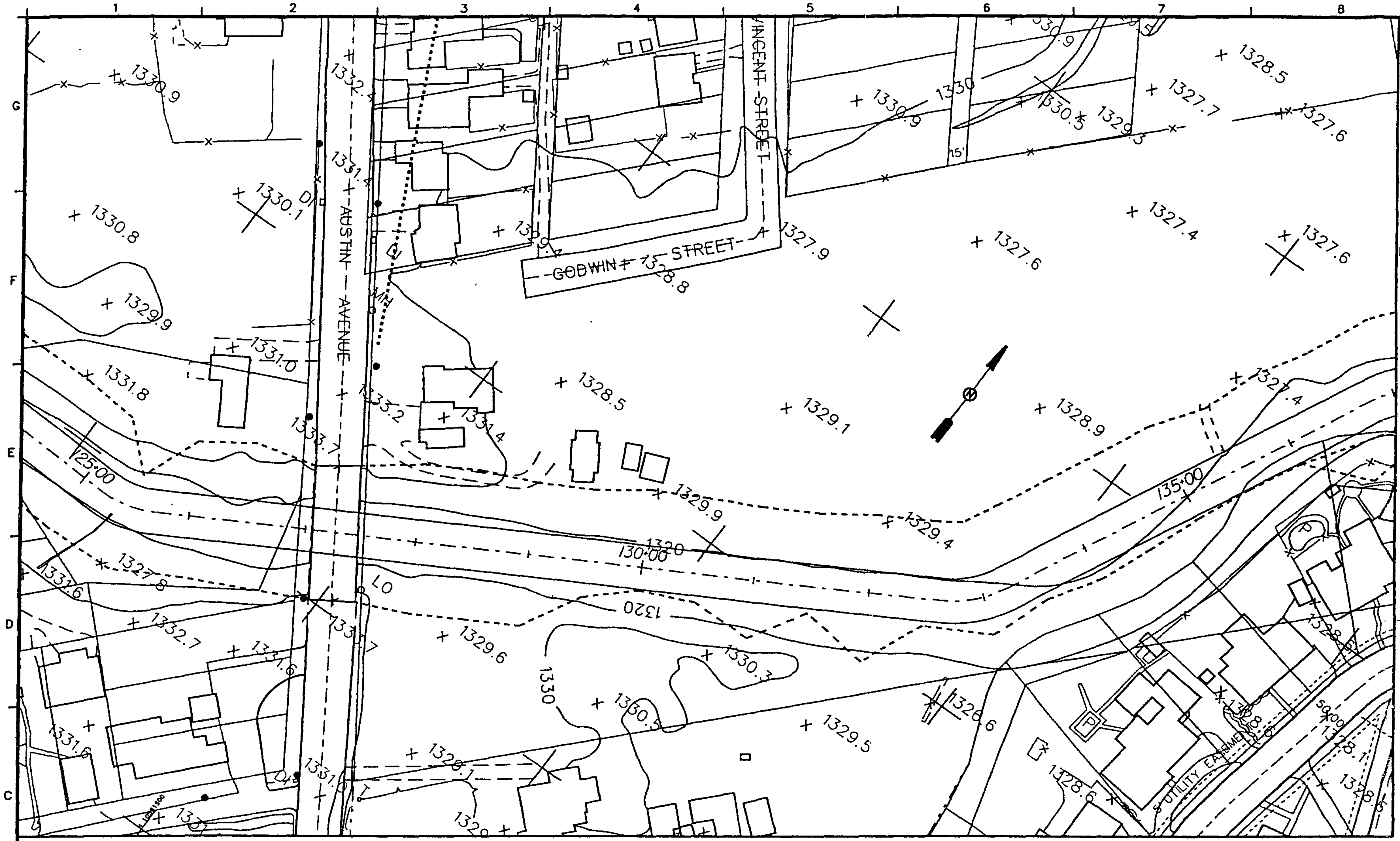
PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 116+00 TO 126+50

SUBMITTED BY:
TERRIL. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 12
CONTR. NO.

CADD FILE NAME: CPCP11.DGN



PLAN

LEGEND

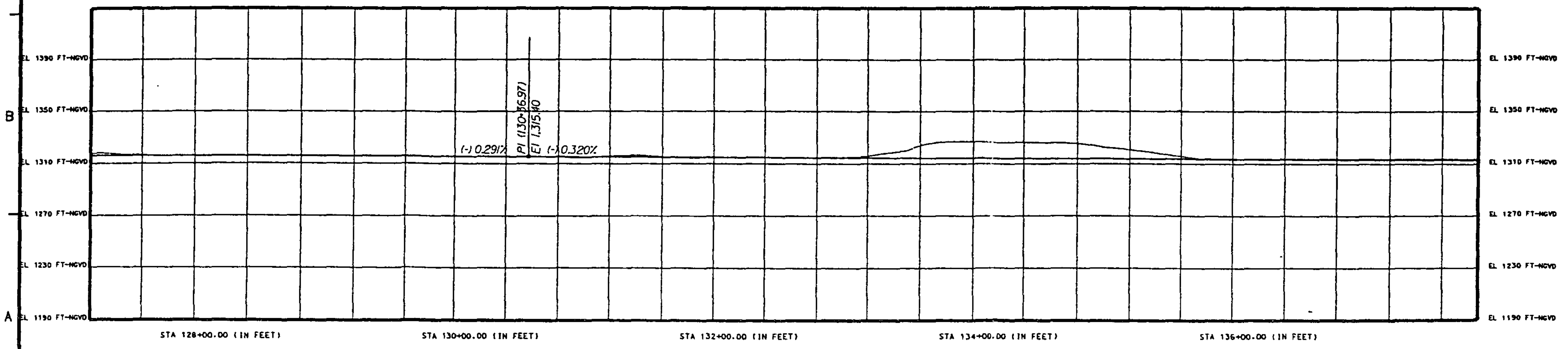
CENTERLINE OF IMPROVEMENT

PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)

IMPROVED CHANNEL PROFILE

EXISTING GROUNDLINE PROFILE

EXISTING MAJOR CONTOUR 1350



CENTERLINE PROFILE

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA

DRAWN BY: L. MENDOZA

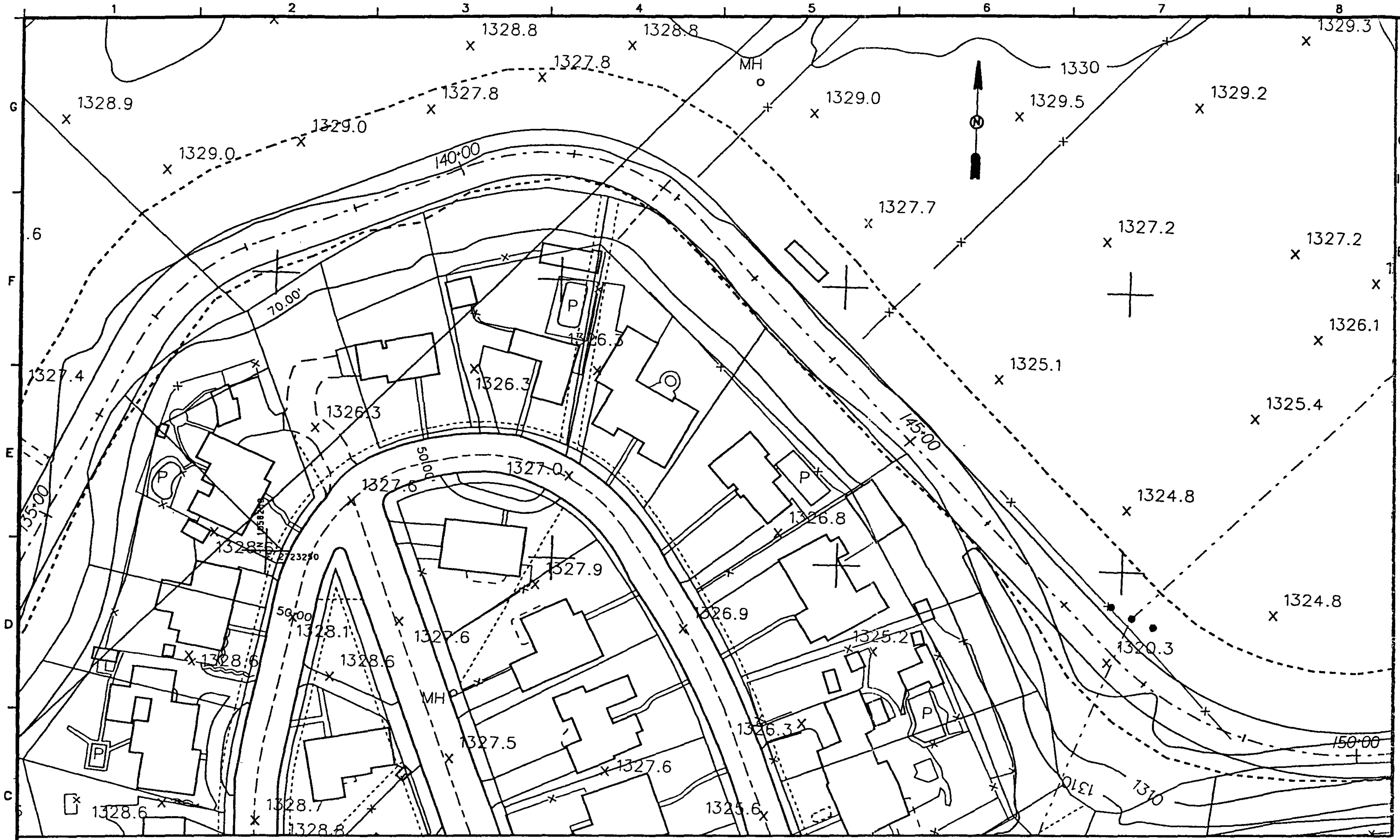
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 126+50 TO 138+00

SUBMITTED BY:
TERRIL. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO
DATED:
CONTR NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 13
CONTR NO.



PLAN

LEGEND

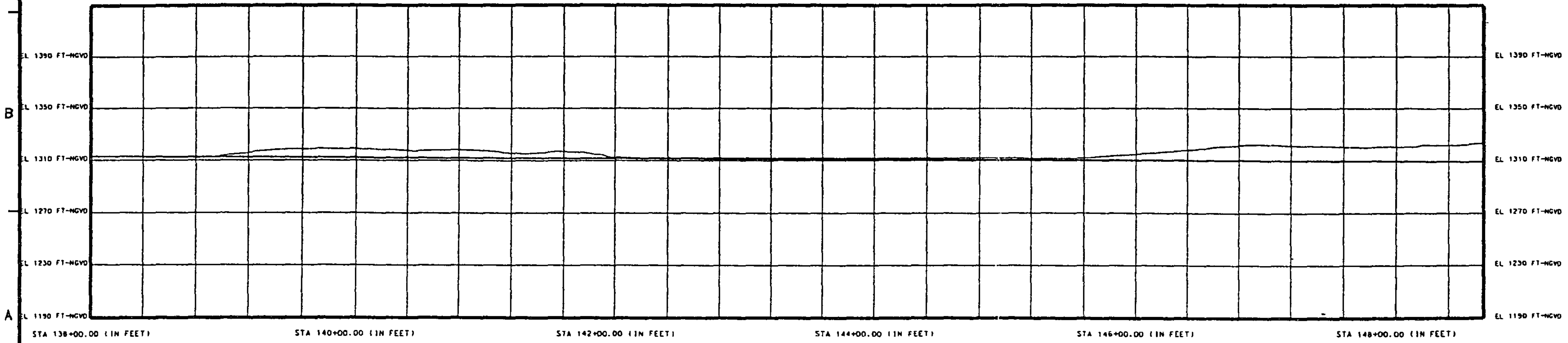
CENTERLINE OF IMPROVEMENT

PERMANENT EASEMENT
(LIMIT OF IMPROVEMENT)

IMPROVED CHANNEL PROFILE

EXISTING GROUNDLINE PROFILE

EXISTING MAJOR CONTOUR 1350



CENTERLINE PROFILE

REFERENCE FILE NAME | REFERENCE FILE DESCRIPTION

SYM | D.O. NO. | ACTION | DATE | DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

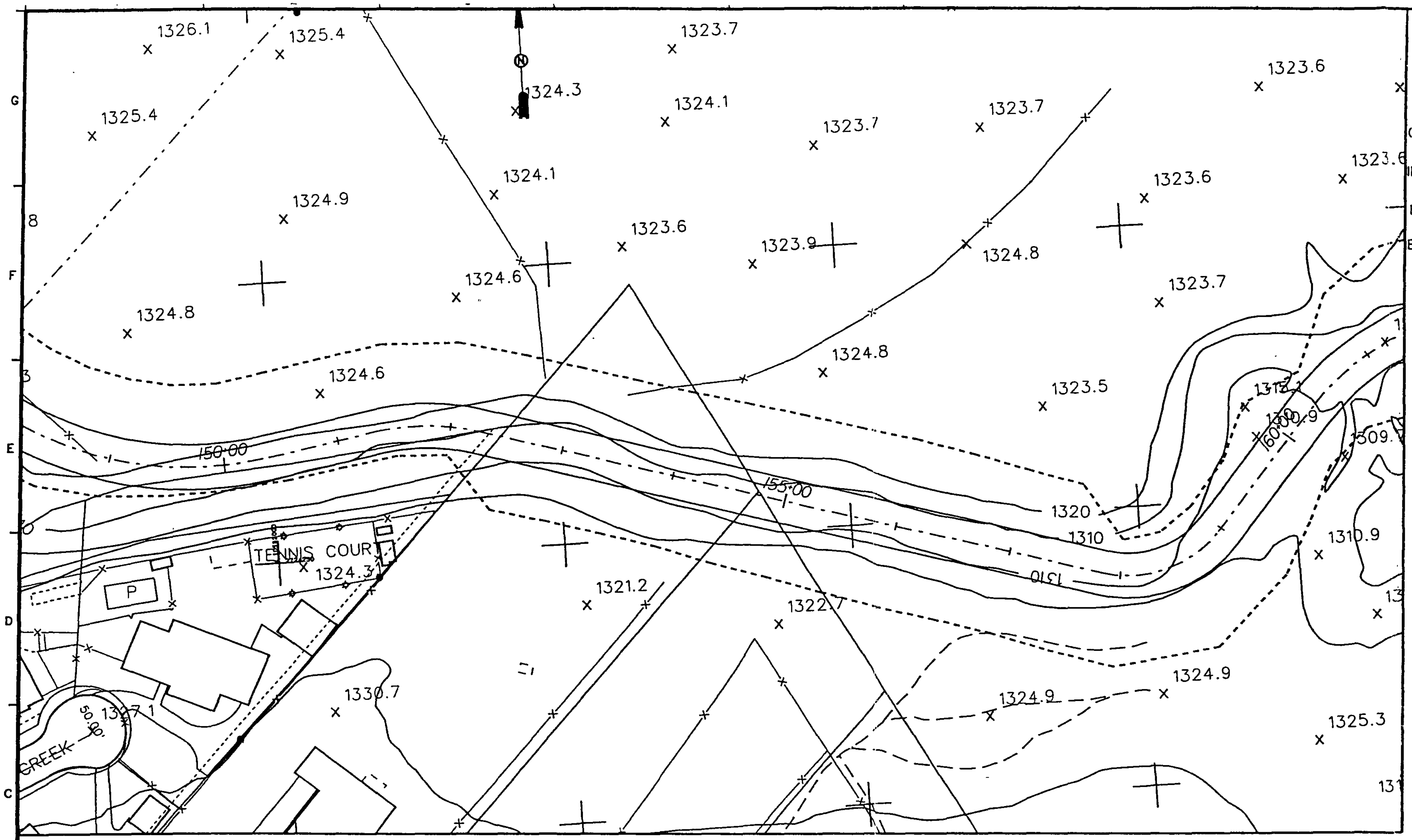
PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 138+00 TO 148+00

SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
OF
SEQUENCE NO.
14
CONTR. NO.

CADD FILE NAME: CPCP13.DGN



PLAN

LEGEND

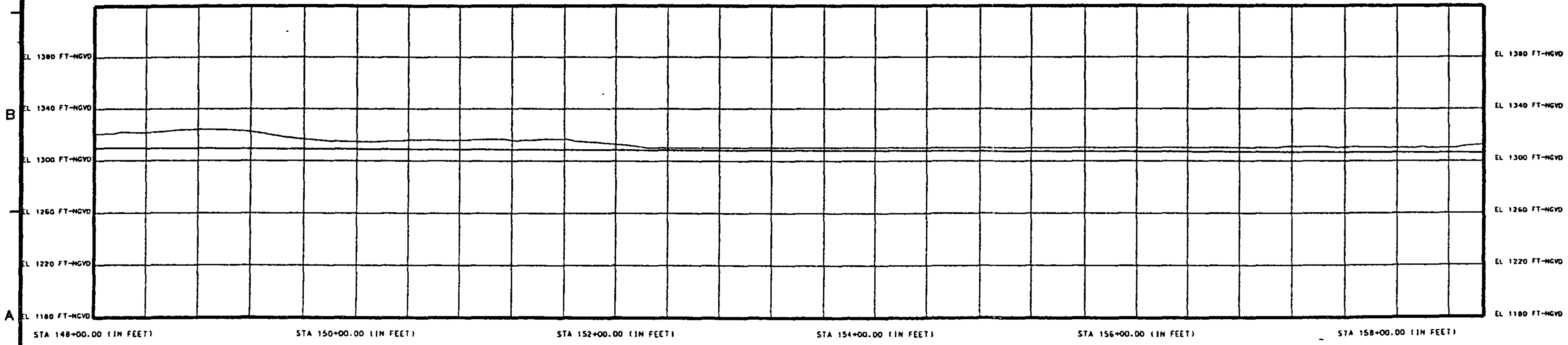
CENTERLINE OF IMPROVEMENT

PERMANENT EASEMENT (LIMIT OF IMPROVEMENT)

IMPROVED CHANNEL PROFILE

EXISTING GROUNDLINE PROFILE

EXISTING MAJOR CONTOUR 1350



CENTERLINE PROFILE

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

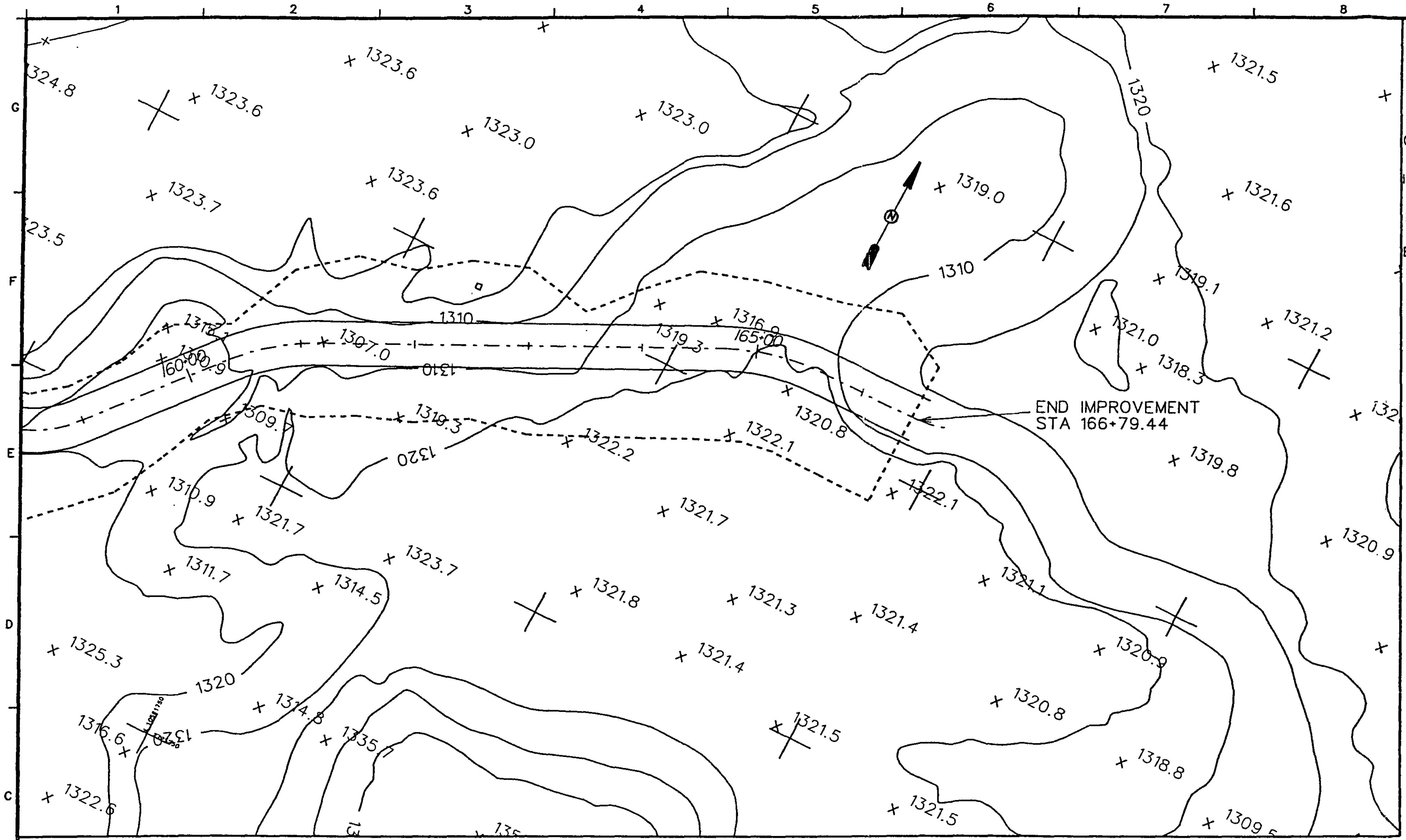
PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 148+00 TO 158+50

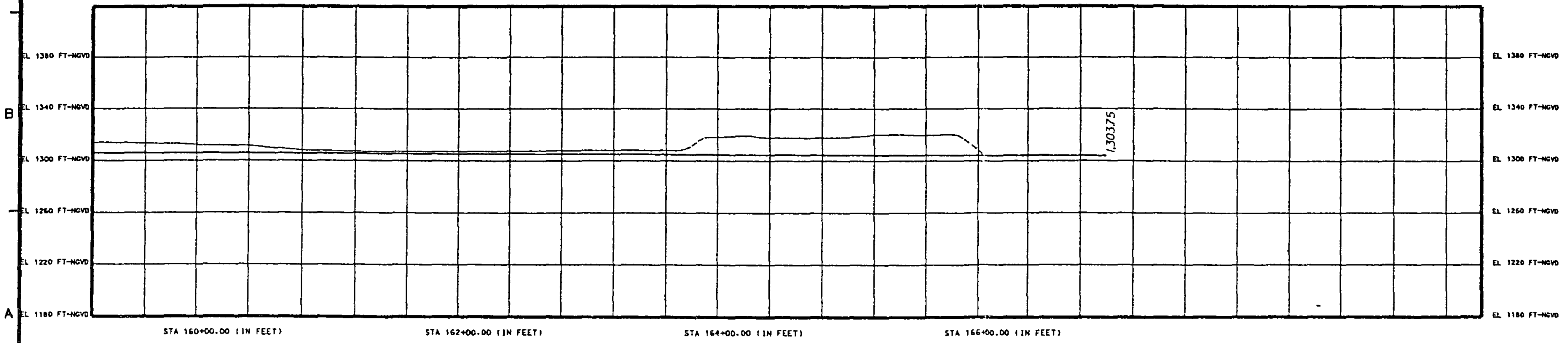
SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 15
CONTR. NO.

CADD FILE NAME: CPCP14.DGN



PLAN



CENTERLINE PROFILE

LEGEND

- CENTERLINE OF IMPROVEMENT —·—·|—·—
- PERMANENT EASEMENT (LIMIT OF IMPROVEMENT) - - - - - -
- IMPROVED CHANNEL PROFILE ———
- EXISTING GROUNDLINE PROFILE ·········
- EXISTING MAJOR CONTOUR ~1350~

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

PLAN AND PROFILE
STA 158+50 TO 166+79.44

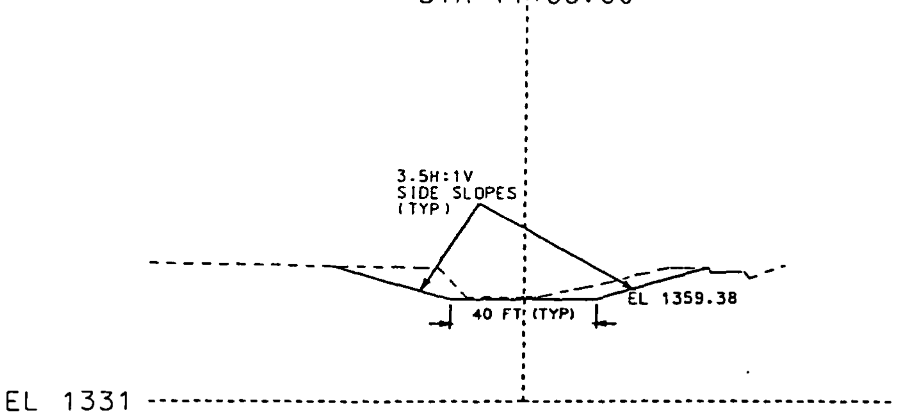
SUBMITTED BY:
TERRI L. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO. 16
CONTR. NO.

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

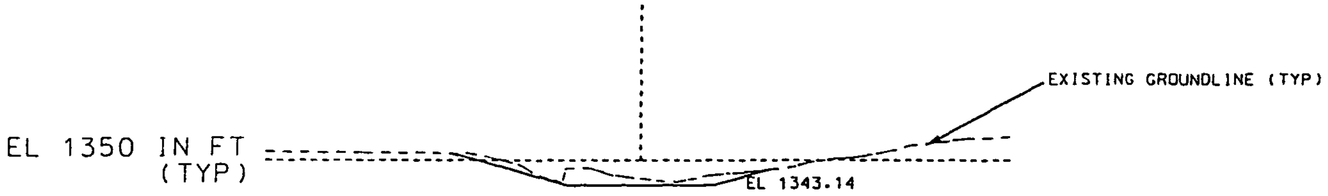
CADD FILE NAME: CPCP15.DGN

STA 11+00.00



SEE SEQ. NO. 2 FOR PLAN LOCATION

STA 65+50.00

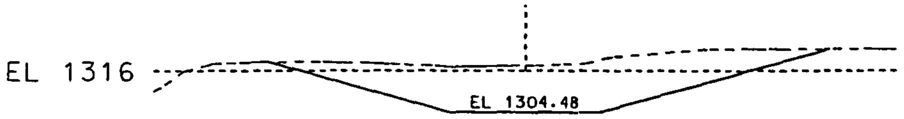


SEE SEQ. NO. 7 FOR PLAN LOCATION

STA 117+00.00

SEE SEQ. NO. 12 FOR PLAN LOCATION

STA 164+50.00



SEE SEQ. NO. 16 FOR PLAN LOCATION

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING/CONSTRUCTION
DIVISION
DESIGN BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: L. MENDOZA
DRAWN BY: L. MENDOZA
REVIEWED BY: E. MARTINEZ

PECAN BAYOU
BROWNWOOD, TEXAS
WILLIS CREEK
CHANNEL IMPROVEMENT

TYPICAL CROSS-SECTIONS

SUBMITTED BY:
TERRIL. NOLEN, P.E.
CHIEF, SITE DEVELOPMENT SECTION

SOL. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
OF
SEQUENCE NO. 17
CONTR. NO.

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

CADD FILE NAME: CPECEXXS2.DGN

SUB-APPENDIX D

STRUCTURAL DESIGN

SUB-APPENDIX D

STRUCTURAL DESIGN

Modification to existing Willis Creek Crossings

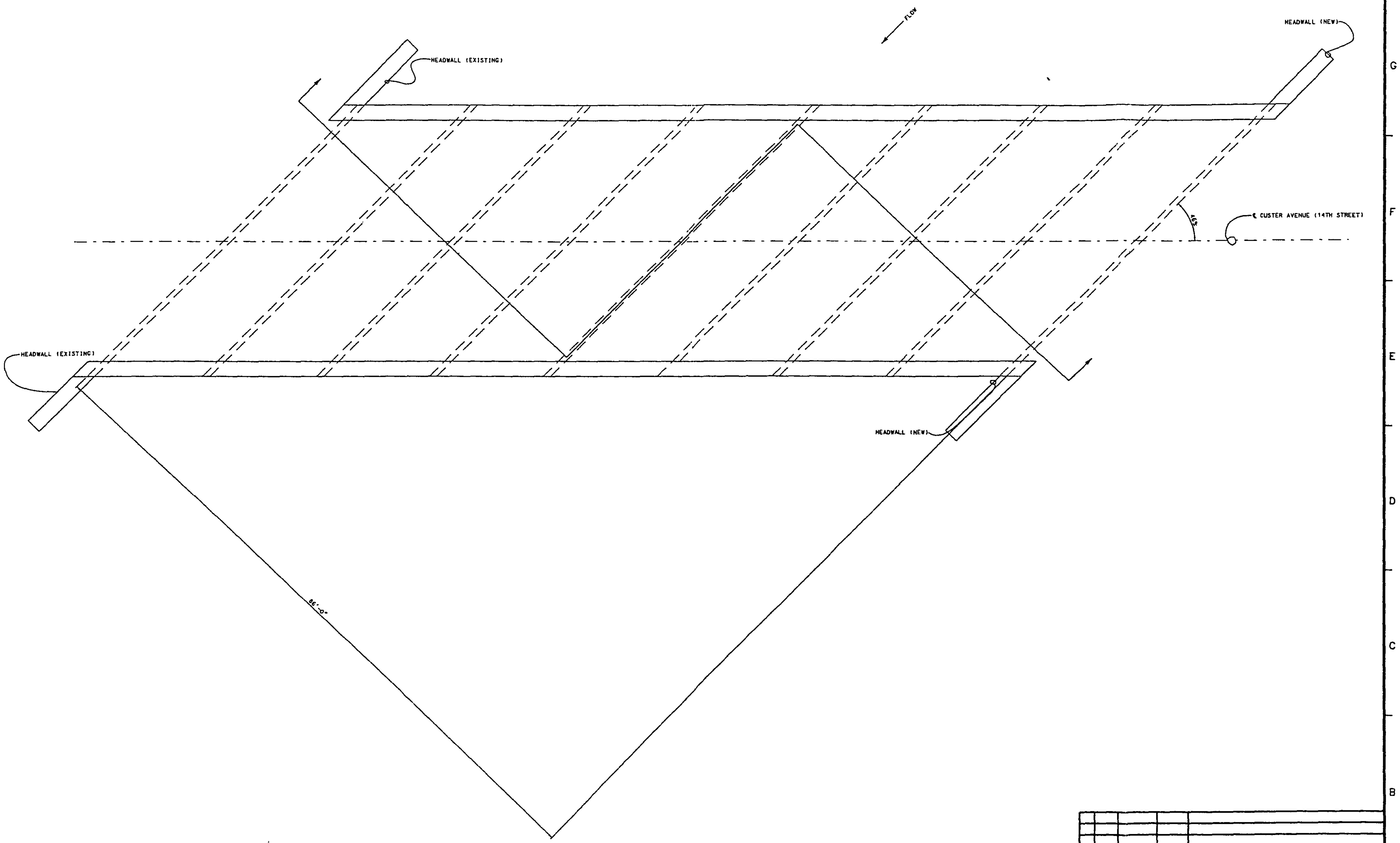
The study consisted of examining the box culverts that carries fourth (4th) street and Custer Avenue (14th street) across Willis creek.

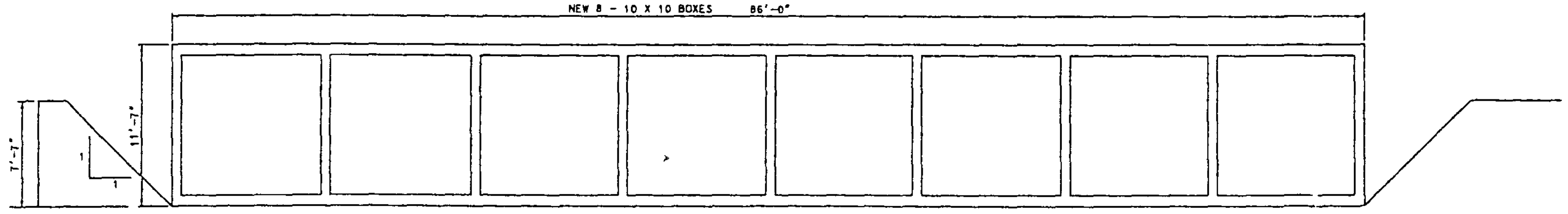
The box culvert on 4th street that crosses Willis Creek is a 4 barrel 10' X 8' box culvert. The recommended hydraulic design requires that an additional 3 barrel 10' wide X 8' deep culvert be constructed adjacent to the existing culvert. The recommended bottom width of the channel is 45'. Therefore, it will be necessary to widen the channel to a width of approximately 75 feet locally by transitioning the recommended channel width into and out of the enlarged box culvert.

Custer avenue (14th Street) crosses Willis Creek on a 4 barrel 8' X 6' box culvert. The recommended hydraulic design requires that the existing box culvert be removed and an 8 barrel 10' X 10' box culvert be constructed. The width of an 8 barrel box culvert is approximately 84'. The bottom width of the channel is 45'. Therefore, it will be necessary to widen the channel to a width of approximately 84 feet locally by transitioning the recommended channel width into and out of the enlarged box culvert.

Texas Department of Highways standard box culverts and headwalls will be used in the design of the modification of the two box culverts on Willis creek.

Figures are attached depicting box culverts at Custer Avenue (14th Street), 4th Street, and typical parallel wing walls.





NOT TO SCALE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

REFERENCE FILE NAME	REFERENCE FILE DESCRIPTION

ENGINEERING DIVISION
CIVIL PLANNING & ENGINEERING BRANCH

U S ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:

DRAWN BY:

REVIEWED BY

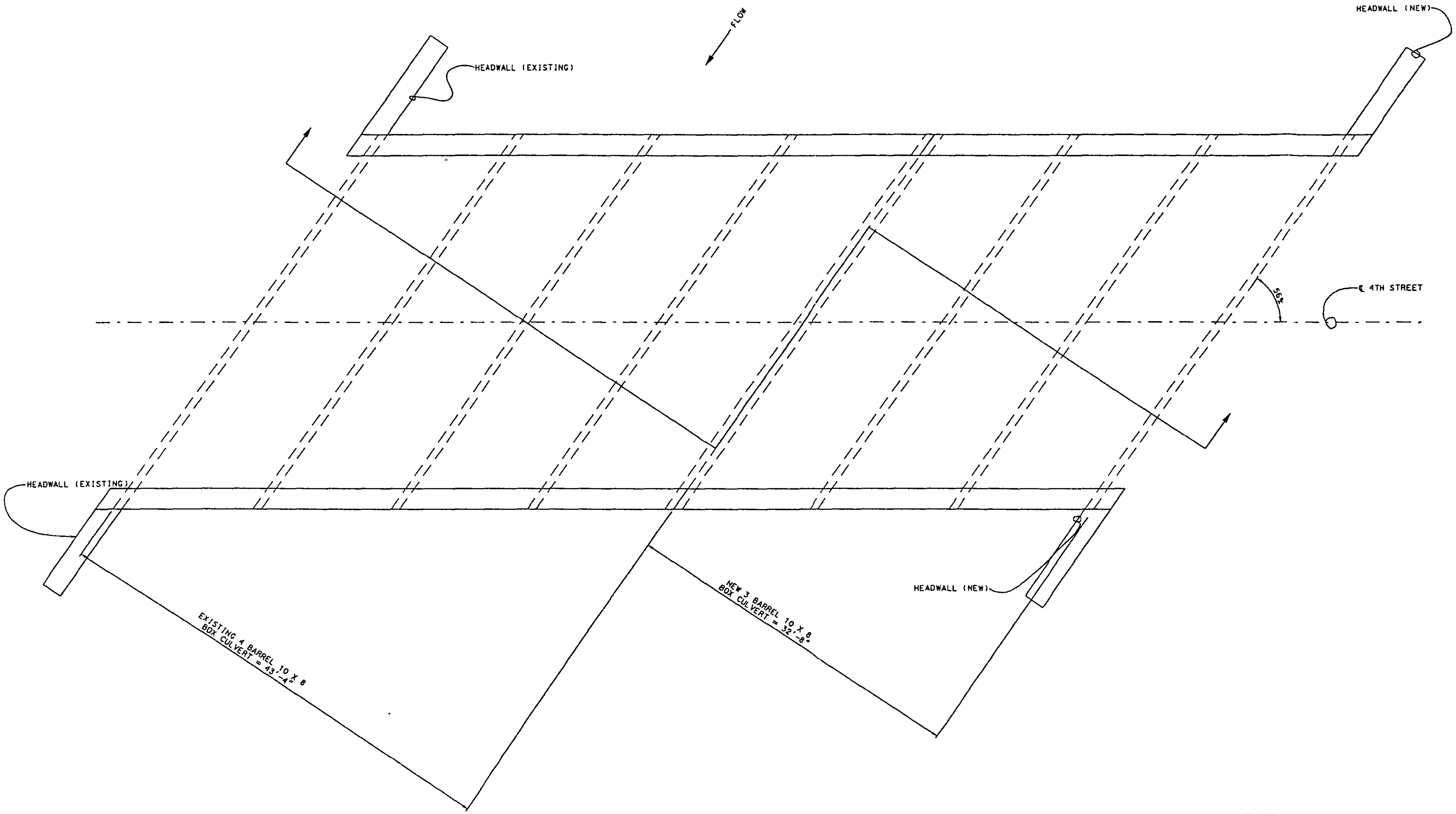
PECAN BAYOU WATERSHED
BROWNWOOD, TEXAS

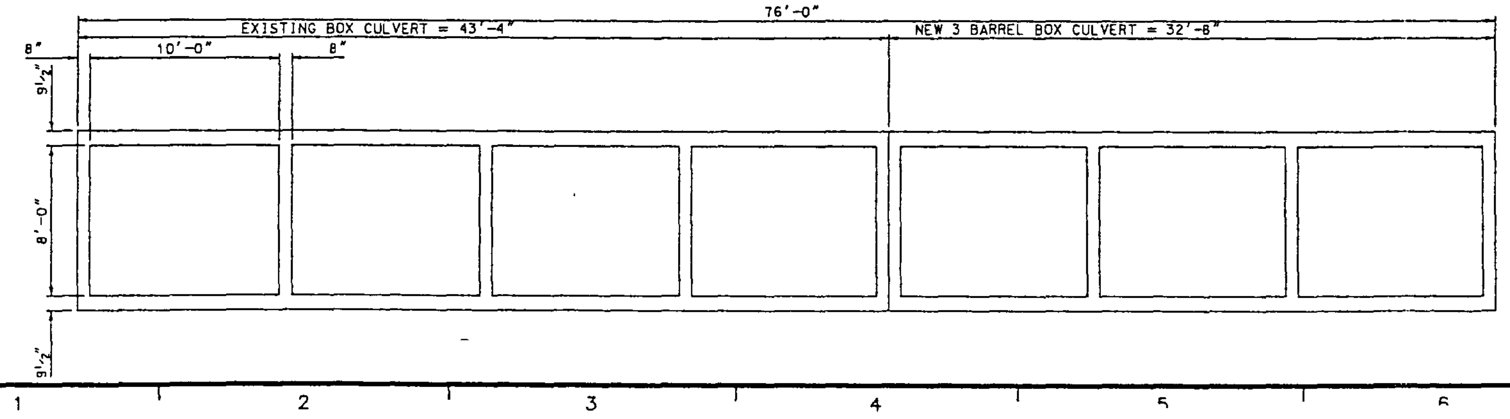
CULVERTS
CUSTER AVENUE (14TH STREET)
OVER WILLIS CREEK

SUBMITTED BY:

WILLIAM A. WALLACE, P E
CHIEF, STRUCTURAL SECTION

SOL NO
DATED
CONTR NO
DRAWING NUMBER
SHEET NO
1 OF 3
SEQUENCE NO.
CONTR NO





NOT TO SCALE

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING DIVISION
CIVIL PLANNING & ENGINEERING BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

PECAN BAYOU WATERSHED
BROWNWOOD, TEXAS

CULVERTS

4TH STREET CULVERT
OVER WILLIS CREEK

SUBMITTED BY
WILLIAM A. WALLACE, P.E.
CHIEF, STRUCTURAL SECTION

SOL NO
DATED
CONTR NO
DRAWING NUMBER
SHEET NO
2 OF 3
SEQUENCE NO
CONTR NO

CADD FILE NAME

REFERENCE TXT NAME
REFERENCE FILE DESCRIPTION

TABLE OF DIMENSIONS & REINFORCING STEEL
(Wings for One Structure End)

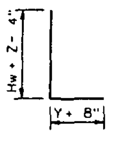
Dimensions					Variable Reinforcing				④ Estimated Quantities per ft of wing (2~Wings)		Estimated Quantities per ft of Toewall (1~Toewall)	
Maximum Wingwall Height Hw	W	X	Y	Z	Bars J1		Bars J2		Reinf (Lb/Ft)	Conc (CY/Ft)	Reinf (Lb/Ft)	Conc (CY/Ft)
					Size	Spa	Size	Spa				
2'-6"	2 -10"	10"	1'- 0"	7'	•4	1'-0"	•4	1'-0"	43 13	0 406	6 85	0 071
2'-9"	2'-10"	10"	1'- 0"	7"	•4	1'-0"	•4	1'-0"	43 80	0 424	6 85	0 071
3'-0"	2'-10"	10"	1'- 0"	7"	•4	1'-0"	•4	1'-0"	44 47	0 444	6 85	0 071
3'-3"	2'-10"	10"	1'- 0"	7"	•4	1'-0"	•4	1'-0"	47 81	0 462	6 85	0 071
3'-6"	2'-10"	10"	1'- 0"	7"	•4	1'-0"	•4	1'-0'	48 48	0 480	6.85	0 071
4'-0"	3'- 2"	1'- 2"	1'- 0"	7"	•4	1 -0"	•4	1'-0"	50 26	0.532	6 85	0 071
4'-6"	3'- 2"	1'- 2"	1'- 0"	7"	•4	1'-0"	•4	1'-0"	54 27	0 568	6 85	0 071
5'-0"	3'- 9"	1'- 7"	1'- 2"	7"	•4	1'-0"	•4	1'-0"	57 94	0 632	6 96	0 075
5'-6"	3'- 9"	1'- 7"	1'- 2"	7"	•4	1'-0"	•4	1'-0"	61 95	0 668	6 96	0.075
6'-0"	4'- 4"	2'- 0"	1'- 4"	7"	•5	1'-0"	•5	1'-0"	75 16	0 730	7 07	0 078
6'-6"	4'- 4"	2'- 0"	1'- 4"	7"	•5	1'-0"	•5	1'-0"	79 54	0 768	7 07	0 078
7'-0"	5'- 0"	2'- 3"	1'- 9"	8"	•5	1'-0"	•5	1'-0"	86 65	0 864	8 07	0 093
7'-6"	5'- 0"	2'- 3"	1'- 9'	8"	•5	1'-0"	•5	1'-0"	91 03	0 902	8 07	,0 093
8'-0"	5'- 6"	2'- 8"	1'-10"	8"	•5	6"	•5	6"	133 54	0.962	8.13	0 095
8'-6"	5'- 6"	2'- 8"	1'-10"	8"	•5	6"	•5	6"	138 96	1.000	8 13	0 095
9'-6"	6'- 0"	2'-10"	2'- 2"	9"	•5	6"	•5	6"	151 43	1 136	8.41	0.110
10'-6"	6'- 5"	3'- 0"	2'- 5"	9"	•6	6"	•5	6"	190 76	1.234	8 57	0 117
11'-6"	7'- 2"	3'- 6"	2'- 8"	11"	•6	6"	•6	6"	224 62	1 438	9 52	0 140
12'-6"	7'- 8"	3'- 9"	2'-11"	1'- 0"	•7	6"	•6	6"	277 90	1 592	9.74	0 157
13'-6"	8'- 2"	4'- 0"	3'- 2"	1'- 2"	•8	6"	•6	6"	343 21	1 804	10 02	0 186
14'-6"	8'-10"	4'- 5"	3'- 5"	1'- 4"	•9	6"	•6	6"	427.43	2 046	10 30	0 218
15'-6"	9'- 6"	4'-10"	3'- 8"	1'- 6"	•9	6"	•7	6"	484 01	2 302	11 24	0 253
16'-0"	9'-11"	5'- 0"	3'-11"	1'- 7"	•9	6"	•7	6"	500.21	2 448	11 47	0 279

TABLE OF WINGWALL REINFORCING
(2~Wings)

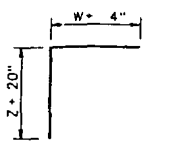
Bar	Size	No	Spa
D1	•5	~	1'-0"
D2	•5	~	1'-0"
E1	•4	~	1'-0"
F	•4	~	1'-0"
G	•5	~	1'-0"
M1	•4	4	~
P	•4	~	1'-0"
V	•4	~	1'-0"

TABLE OF TOEWALL REINFORCING

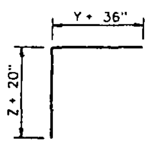
Bar	Size	No	Spa
J3	•4	~	1'-0"
M2	•4	2	~
E2	•4	~	1'-0"



BARS J1



BARS J2



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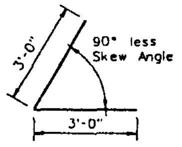
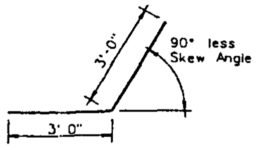


BARS D1



BARS D2

BARS V

WING DIMENSION CALCULATIONS

Formulas (All values are in Feet)

Hw • H + T + C

Lw • (Hw) (SL) Cosine ( ) Φ

For Cast-in-place culverts:

Ltw - [(N) (S) (N+ 1) (U)] (Cosine) Φ

For Precast culverts

Ltw • [(N) (2 U S) • (N+ 1) (0.5')] (Cosine) Φ

Total Wingwall Area (Two Wings ~ S F)

• (2) (Hw) (Lw)

Hw • Height of Wingwall
Lw • Length of Wingwall
Ltw • Culvert Toewall Length
N - Number of Culvert Spans
SL:1 • Channel Slope ratio (Horizontal: 1 Vertical, Usual value is 2 1)
Φ • Culvert Skew

See applicable box culvert standard for S, H, T and U values

GENERAL NOTES:

Designed according to current AASHTO Standard and Interim Specifications

All reinforcing steel shall be Grade 60

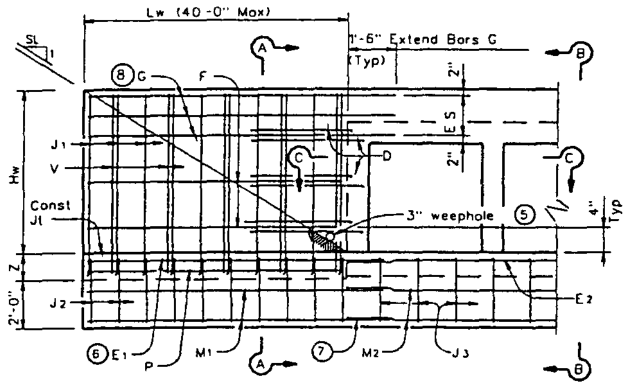
All concrete shall be Class "C" and shall have a minimum 28 day compressive strength of 3600 psi

All reinforcing bars shall be adjusted to provide a minimum of 1 1/4" clear cover.

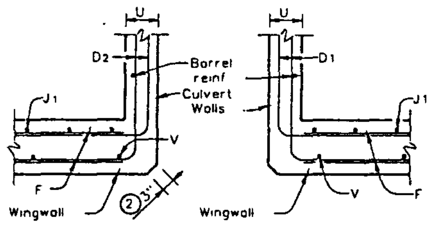
When structure is founded on solid rock, depth of toewalls for culverts and wingwalls may be reduced or eliminated as directed by the Engineer

See BCS sheet for additional dimensions and information

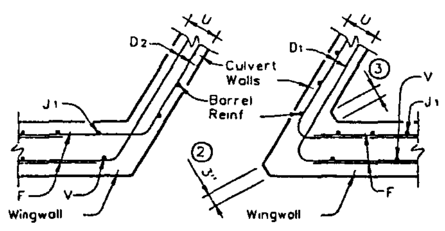
The quantities for concrete and reinforcing steel resulting from the formulas given on this sheet are for Contractor's information only.



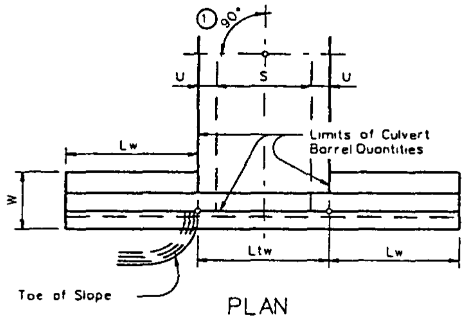
PARTIAL ELEVATION



SECTION C-C

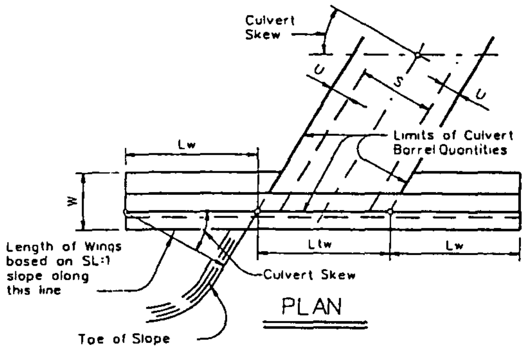


SECTION C-C



PLAN

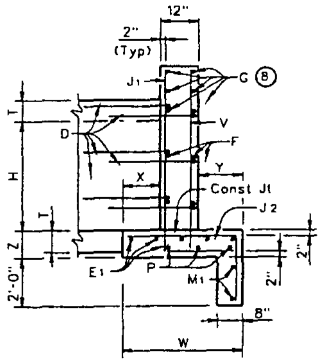
DETAILS FOR NON-SKEWED BOX CULVERTS



PLAN

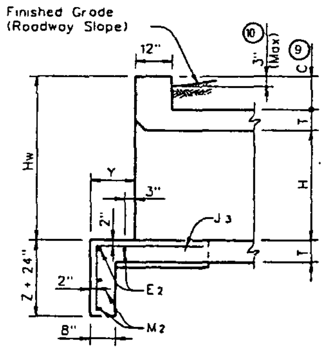
DETAILS FOR SKEWED BOX CULVERTS

(Showing 30° Skew)



SECTION A-A

(Showing Wing Reinf)



SECTION B-B

(Showing Toewall Reinf)

① Skew Angle • 0°

② At discharge end, chamfer may be 3/4"

③ For 15° Skew ~ 1"
For 30° Skew ~ 2"
For 45° Skew ~ 3"

④ Quantities shown are for two wings. To determine total quantities for two wings, multiply the tabulated values by Lw.

⑤ Provide weepholes for Hw - 5'-0" and greater Fill around weepholes with coarse gravel

⑥ Extend Bars E 1'-6" minimum into the bottom slab of the culvert

⑦ Lap Bars M 1 1'-6" minimum with Bars M 2

⑧ Bars G shall be equally spaced at 1'-0" maximum, placed as shown. There shall be at least 4 Bars G per wing.

⑨ 0" min to 5'-0" max For T6 or C6 Rail, see T6-CM standard for additional details. For curbs without rail and greater than 1'-0" high, see ECD standard for additional details Estimated curb heights are shown elsewhere in the plans

⑩ For vehicle safety, curb heights and wall heights shall be reduced, if necessary, to provide a maximum 3" projection above finished grade No changes will be made in quantities and no additional compensation will be allowed for this work

HS20 LOADING

Texas Department of Transportation
Bridge Division

PARALLEL WINGS
FOR SKEWED AND NON-SKEWED
BOX CULVERTS

PW

FILE pwslde01 dgn	DN: GAF	CK: CAT	DW: TxDOT	CK GAF
© TxDOT September 2000	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB HIGHWAY

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LEVELS DISPLAYED
COMMENTS

SYM	D.O. NO.	ACTION	DATE	DESCRIPTION OF REVISION

ENGINEERING DIVISION
CIVIL PLANNING & ENGINEERING BRANCH

U S ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY:
DRAWN BY:
REVIEWED BY:

PECAN BAYOU WATERSHED
BROWNWOOD, TEXAS

CULVERTS

PARALLEL WINGS

SUBMITTED BY
WILLIAM A WALLACE, P E
CHIEF, STRUCTURAL SECTION

SOL NO
DATED
CONTR. NO
DRAWING NUMBER
SHEET NO. 3 OF 3
SEQUENCE NO.
CONTR NO

CADD FILE NAME

SUB-APPENDIX E

HTRW ANALYSIS

SUB-APPENDIX E

HAZARDOUS, TOXIC AND RADIOLOGICAL WASTE (HTRW)

PROJECT DESCRIPTION

The Pecan Bayou Feasibility Study recommends a channel improvement project along Willis Creek in the southern portion of the City of Brownwood, Texas. However, during the course of this study, consideration was given to a project in the eastern portion of the city in which Adams Slough was supplemented by the construction of a diversion channel. This appendix describes the HTRW investigation in each location. The study area along Willis Creek extended from State Highway 377 downstream to the confluence with Pecan Bayou. The recommended structural design entails improving the existing channel by widening its invert and reducing its side slopes. The study area for the diversion channel included both Adams Slough and the main channel of Pecan Bayou from State Highway 377 to the point where Willis Creek joins Pecan Bayou.

PROJECT AREA HTRW OVERVIEW

Development along the southern bank of Willis Creek began early in the 1900's and included the establishment of Camp Bowie by the U.S. Army in 1943. Camp Bowie was used as an infantry, armor and artillery training facility during World War II but was closed shortly after the war's conclusion. An area of land, on the south side of Willis Creek, and south-southwest of the current intersection of Good Shepard Drive and Custer Road, was used as a landfill for the Camp. Extensive field-testing by CH2MHill, under contract to the Tulsa District of the Corps of Engineers, revealed the presence of multiple trenches of debris lying in a northwest to southeast alignment. This evidence begins about 100 feet from the creek centerline and extends southward from there. Additional information and details of the testing are presented on the following pages of this Appendix. There were no other locations in the Willis Creek study area in which HTRW issues were indicated.

In the Adams Slough study area, there is a Burlington Northern Santa Fe railroad yard to the west, relatively undeveloped land to the east and south, and commercial development and public roadways to the north. There were three separate areas of concern identified during site visits and records searches. The first, a wastewater treatment plant disposal site, was active prior to 1936. Two other sites were used as landfills by the city, one up until 1964 and the other from 1964 until 1974. The proposed diversion channel crossed the latter referenced site; therefore a field investigation was performed to determine the extent of the debris field. Typical, non-hazardous, household refuse was found at this location and would need to have been dealt with if the recommended plan had included this channel. Additional information and details of the testing are presented on the following pages of this Appendix.

WILLIS CREEK STUDY AREA

SITE INVESTIGATION

General

This information is provided in support of the recommended plan presented in this Feasibility Report. The plan proposes widening and generally improving Willis Creek over much of its length through the City of Brownwood. An initial assessment was first performed during the preparation of the Pecan Bayou Reconnaissance Study, published in 1994. That study identified only one site in the vicinity of Willis Creek that could potentially present HTRW issues. That site is an area that was once a landfill for Camp Bowie, a Formerly Used Defense Site (FUDS), located on the southern edge of the creek and north of the W.T. Harris Building on Stephen F. Austin Street, see Figure K-1. The recommended plan involves improvements to the existing watercourse in the area of this former landfill; therefore a detailed site investigation was conducted to determine the nature and extent of debris at the site.

Previous Investigation

In 1998, the Tulsa District Corps of Engineers conducted both a visual and analytical survey of the site under the FUDS program. The purpose of the investigation was to determine if the former use of the land had resulted in any soil contamination. Testing was specifically directed at the landfill area. A portion of the site was visually inspected, seven test pits were made, and both soil and water samples were collected for chemical analysis. This investigation confirmed the existence and the general location of the landfill, but did not define its limits in any way.

Recent Investigation Activities

In March 2000, the Tulsa District Corps of Engineers conducted an additional investigation of the former Camp Bowie site under the FUDS program. The investigation included an electromagnetic (EM) survey, 14 soil samples, 4 geotechnical samples, 1 soil sample from beneath the stream, 3 sediment samples and 3 water samples from Willis Creek. For the purposes of this report, only the EM survey is of interest.

The EM survey was conducted over the area of the landfill for the purpose of determining the extent of the debris field. The survey was performed using a Geonics EM-31 and a digital data recorder that measures bulk electrical conductivity to identify buried metallic objects typically found in landfills. Results of the survey indicate that the northern limit of the landfill material is approximately 100 feet from the centerline of Willis Creek. Figure K-2 on the following page shows the general location and orientation of the landfill trenches. Although this delineation has not been field verified by boring or excavation, there is no reason to suspect that landfill material extends significantly further to the north. Since the alignment of the recommended plan closely follows the existing creek in this area, and the extent of the proposed improvement is no greater than 70 feet, construction activities will not disturb the landfill.

ADAMS SLOUGH STUDY AREA

SITE INVESTIGATION

General

This information is provided as documentation of the investigations performed in the vicinity of Adams Slough. The project presented in this document as the recommended plan does not include any construction within the Adams Slough study area.

An initial assessment was first performed in support of the Pecan Bayou Reconnaissance Study, published in 1994. At that time, the study area encompassed most of the Pecan Bayou watershed and included all of the City of Brownwood. The area around Adams Slough was identified as containing a USDA Pecan Field Station, within which there were two former municipal landfills. The site was recommended for additional investigation during any future study. Information regarding each of these sites is presented in the following sections. As this Feasibility Study progressed, and an alignment was established for a diversion channel along Adams Branch, the landfill that was actively used by the city between 1964 and 1974 was identified as lying within the footprint of the proposed channel. (See Figure K-3.) A detailed investigation of this landfill was performed in August of 1999 and the results are presented in the "Steele Property" paragraph below.

USDA W.R. Poage Pecan Bayou Field Station

History

The USDA field station was created in 1930, by a property-sharing contract between the USDA and the City of Brownwood. The first research facility structures were erected in the summer of 1931, with pecan orchards developed on approximately 65 acres beginning in 1932. A city property map dating before 1950 depicts the City of Brownwood Wastewater Treatment Plant (WWTP) in the central portion of the current field station property. The map also depicts a four-acre "City of Brownwood Dump Ground" located east of the WWTP, adjacent to a meander in Pecan Bayou. According to a letter dated 22 September 1967, the city evidently used the WWTP facility to some degree until 1951. The letter also mentions that the City Sanitation Department had been filling an oxbow of Adams Slough located on a tract of property belonging to Oliver Steele, this property being located "at the end of Sharp Street". This "Steele Property" site is located at the south central boundary of the USDA facility, adjacent to Adams Slough, and is estimated to have begun landfilling operations in about 1964. In 1979, the "Steele Property", including the landfill site, was transferred to the USDA. Currently, the USDA field station has a large established pecan orchard planted in the area formerly used by the WWTP, and a newer pecan orchard on the "Steele Property". However, there is no orchard within the confines of the former landfill.

"Steele Property" Landfill

One section of the proposed diversion channel crosses the landfill on the "Steele Property" that was active from 1964 to 1974. In August of 1999, this site had a dense cover of grass, two to three feet tall, with scattered cactus and mesquite. The ground over the landfill area had a somewhat irregular appearance, with many large depressions, whereas the surrounding land was generally flat. Although the city stopped using the site as a landfill in 1974, individuals continued to dump waste illegally until the city fenced the site several years ago. A representative of the field station related that employees had, prior to 1974, disposed of pesticides in the landfill and have subsequently inadvertently penetrated the waste while planting trees or installing a waterline. In addition, the surface of the area in question has experienced some subsidence over the years, in spite of at least one effort to re-level the area with imported fill material. Imported meaning "from another location", not "from a foreign country".

IN 1996, the USDA contracted with Ambiotec Environmental Consultants, Inc. of Harlingen, Texas to perform a limited site investigation of three locations on the USDA property, including this landfill site. The purpose of the investigation was to determine whether soils, groundwater, surface water and subsurface gas had been affected by contaminants relating to past operations. The study included the collection of souls, groundwater, surface water and subsurface gas. Results are summarized as follows:

Native soils from below the disposal area did not contain any contaminants with concentrations above TNRCC action levels.

Analytical results of subsurface gas samples indicate methane levels that exceed cleanup levels set by the Texas Natural Resource Conservation Commission (TNRCC) in 10 out of 24 samples.

Three metals were found to exceed TNRCC cleanup levels in one of eight groundwater samples; barium, 13.4 mg/l vs. 2.0, chromium 1.29 mg/l vs. 0.10 and lead 1.42 mg/l vs. 0.015.

If the diversion channel initially proposed along Adams Slough had not been eliminated for other economic reasons, these results would have had to have been dealt with during the final design phase of the project. However, because this aspect of the flood damage reduction study is no longer under consideration, no further investigation effort is warranted.

CONCLUSIONS AND RECOMMENDATIONS

The recommended channel improvement plan presented in this Feasibility Study will not encounter any hazardous, toxic or radiological wastes as it is currently aligned. The project will not require any additional investigation, nor will any HTRW-related regulations need to be followed.

However, should there be any southward realignment of the proposed channel improvement in the former Camp Bowie landfill area, the likelihood of excavating landfill material is very high and this issue will need to be revisited.

SUB-APPENDIX F

GEOTECHNICAL

SUB-APPENDIX F

GEOTECHNICAL DATA

TABLE OF CONTENTS

PLATES

1. General. The U.S. Army Corps of Engineers, Fort Worth District has conducted a study to determine the feasibility of providing added flood protection measures to alleviate flooding within the Pecan Bayou watershed. This study is a result of the findings and recommendations of the Reconnaissance Study published in March 1994, and was requested and sponsored by the city of Brownwood. To alleviate flooding problems adjacent to Adams Slough, located in the northeastern section of the city of Brownwood, a diversion channel, measuring 8,800 feet in length was to be constructed north of Adams Slough. The Adams Slough diversion channel was to have a bottom width of approximately 45 feet, with 1-vertical-on-3-horizontal (1V:3H) slopes. The diversion channel was to be excavated to depths ranging from approximately 9 feet to 12 feet below existing grade. The Adams Slough diversion channel option was effectively eliminated from consideration in late Fall 2000, after the geotechnical field investigation and laboratory testing had been completed. The results of the geotechnical field investigation and laboratory testing of soil and rock samples collected within borings drilled along the Adams Slough diversion channel alignment are included for information record purposes. To alleviate flooding problems adjacent to Willis Creek, located in the southern part of the city of Brownwood, proposed channel modifications are recommended. The project alignment along Willis Creek begins east of Highway 377 and extends eastward for a distance of approximately 16,000feet. The modified Willis Creek channel will be configured to a 40-foot bottom width, with 1V:3.5H slopes.

2. Geology.

2.1. Physiography. Brownwood is located within the Osage Plains Section of the Central Lowlands physiographic province. The area is characterized by moderate topographic relief, with river valleys incising the gently dipping Pennsylvanian age deposits, which are capped by more resistant, mesa-forming Cretaceous age limestone outcrops.

2.2. Stratigraphy. The city of Brownwood, which encompasses both Willis Creek and the Adams Slough diversion channel options, is situated within the Pennsylvanian age Strawn Group, which consists of alternating sequences of limestone, shale, sandstone, siltstone, and conglomerate. The Strawn Group has a maximum thickness of approximately 1500 feet. In the areas near Willis Creek and the Adams Slough diversion channel, the Pennsylvanian age strata are overlain by Quaternary age alluvial deposits of clay, silt, sand, and gravel.

2.3. Structural Geology. Regional dip of the Pennsylvanian age strata is toward the west-northwest at a rate of about 60 feet per mile. Although small faults and flexures are common in the Pennsylvanian strata, no significant fault trends were noted during a review of geologic maps of the area. Brownwood lies within seismic zone 0, according to the Uniform Building Code Seismic Zone Map, as presented in EM 1110-2-1806, dated 31 July 1995, subject: Earthquake Design and Evaluation for Civil Works Projects.

3. Field Investigation.

3.1. General. The Fort Worth District drilled a total of ten (10) geotechnical test holes in the project area during March 2000. Of the total, three (3) borings (3ST-1, 6A-3, and 3ST-4) were drilled along the Adams Slough diversion channel alignment, and seven (7) borings (3ST-5 through 6A-11) were drilled along the Willis Creek channel alignment. The borings were drilled using a Failing 1500 truck-mounted drill rig for the purpose of determining subsurface conditions and obtaining representative soil and rock samples for laboratory testing. Soil sampling and test hole advancement was accomplished using 6- and 8-inch diameter solid-stem short-flight helical augers, a 7 7/8-inch rockbit, and a nominal 4-inch diameter diamond core bit. Undisturbed soil sampling was accomplished using a nominal 3-inch diameter Shelby tube sampler. The borings were advanced to depths ranging from 2.5 feet to 40 feet below existing grade at the time of drilling. Refer to Plates F-1 and F-2 for plans of borings.

3.2. Adams Slough Diversion Channel.

3.2.1. General. Borings 3ST-1, 6A-3, and 3ST-4 were drilled along the Adams Slough diversion channel. The borings were advanced to depths ranging from 20 to 40 feet below the existing grade at the time of drilling. The depth of the proposed channel invert varies from approximately 9 to 12 feet below existing grade, and deepens to approximately 17 feet below ground surface at the intersection of the diversion channel and Pecan Bayou.

3.2.2. Subsurface Conditions. Overburden materials encountered within the Adams Slough diversion channel borings are alluvial deposits of low to high plasticity clays (CL and CH), underlain by silty sand (SP-SM), and gravel/cobble near the Pecan Bayou channel. Brown, silty, sandy, low to high plasticity clays were encountered to 20 feet (total drilling depth) in borings 3ST-1 and 6A-3. Moisture content in the clays was described as increasing with depth, and hardness was described as decreasing with depth. In boring 3ST-4, drilled near the Pecan Bayou channel, the clays were underlain by red yellow to light brown, poorly graded, silty, gravelly sand, encountered at 16 feet below grade, and by coarse to fine, moist to wet, dense, light brown to brown gravel and cobble (with cementation noted) encountered at 21.5 feet below existing grade. A light gray, massive, hard to very hard (rock classification), arenaceous, angular, moderately to well-cemented conglomerate of the Pennsylvanian age Strawn Group was encountered within boring 3ST-4 at 31 feet below existing grade, and continued to at least 40 feet (total boring depth). Refer to Plates F-3 through F-5 for logs of borings 3ST-1 through 3ST-4.

3.2.3. Groundwater Level. Groundwater conditions were monitored during drilling, upon completion of drilling, and at 24 hours after completion of drilling. Static water levels were measured at depths of 16.5 feet and 26.0 feet below ground surface in borings 3ST-1 and 3ST-4, respectively. It should be noted, however, that groundwater conditions are relative to the time of drilling, annual precipitation, and local drainage conditions.

3.2.4. HTRW Borings. Borings MLSB-1 through MLSB-4 were drilled concurrently with the geotechnical investigation borings along the Adams Slough diversion channel alignment to delineate the limits of a municipal landfill within the project alignment, and to obtain soil and leachate samples for HTRW testing. Refer to the HTRW Appendix for a complete discussion of the HTRW field investigation. It should be noted that borings MLSB-2 and MLSB-3, located outside of the landfill limits, encountered clays similar to those encountered in geotechnical borings 3ST-1 and 6A-3. Logs of borings for MLSB-1 through MLSB-4 are included for reference on Plates F-6 through F-9.

3.3. Willis Creek.

3.3.1. General. Borings 3ST-5 through 6A-11 were drilled along the Willis Creek channel modification alignment. The borings were advanced to depths ranging from 2.5 to 20 feet below the existing grade at the time of drilling. The depth of the proposed channel invert is typically less than 5 feet below the existing channel invert. Borings were typically drilled along the channel banks as close as possible to Willis Creek, although boring 6A-11 was drilled within the channel.

3.3.2. Subsurface Conditions. Overburden materials encountered within the Willis Creek channel borings are interbedded alluvial deposits of low to medium plasticity clays (CL), clayey sands (SC), and gravel. There is considerable variation in the type and thickness of overburden materials encountered within the seven borings drilled along Willis Creek. The low to medium plasticity clay is typically brown to light brown, medium stiff to hard (depending on moisture content), silty, sandy, and gravelly. Sand and gravel, encountered in borings 3ST-7 through 6A-11, is typically dark brown to light brown, poorly graded, silty, and clayey, with moisture content increasing with depth. The alluvial deposits overlay limestone and shale of the Pennsylvanian age Strawn Group. Limestone primary was encountered beneath the overburden in borings 3ST-5, 6A-6, and 6A-11 at respective depths below ground surface of 2.5 feet, 5.5 feet, and 3.9 feet. Shale primary was encountered beneath the overburden in borings 3ST-7, 6A-8, and 3ST-9 at respective depths below ground surface of 11.8 feet, 17.8 feet, and 2.0 feet. Primary materials were not encountered in boring 3ST-10. The limestone is described as very hard (rock classification), yellow brown to light gray, jointed, and arenaceous, with a nodular appearance in an outcrop (at the location of boring 6A-11). The shale is described as very soft to medium hard (rock classification), yellow brown to gray to red, blocky to massive, silty, and calcareous, with thin limonite seams below approximately 11 feet below grade (channel bank). Refer to Plates F-10 through F-16 for logs of borings 3ST-5 through 6A-11.

3.3.3. Groundwater Level. Groundwater conditions were monitored during drilling, upon completion of drilling, and at 24 hours after completion of drilling. Static water levels were measured at depths of 8.0 feet, 12.0 feet, 13.3 feet, and 3.5 feet below ground surface in borings 3ST-7, 6A-8, 3ST-10, and 6A-11, respectively. It should be noted, however, that groundwater conditions are relative to the time of drilling, annual precipitation, and local drainage conditions.

4. Laboratory Testing.

4.1. General. Representative samples recovered from the borings were subjected to laboratory testing for identification, moisture content, grain-size distribution, Atterberg limits, density, unconfined compressive strength, triaxial compressive strength (Q-strength), and direct shear (consolidated-drained/S-test).

4.2. Adams Slough Diversion Channel. Samples of clays encountered within borings drilled along the Adams Slough diversion channel were determined to have liquid limits ranging from 32 to 54 percent, plastic limits ranging from 14 to 20 percent, moisture contents ranging from 11.8 to 23.7 percent, unit dry weights ranging from 99.1 to 122.3 pounds per cubic foot (pcf), and triaxial compressive strengths ranging from 0.23 to 6.3 tons per square foot (tsf). The non-plastic silty sand encountered in boring 3ST-4 was determined to have a moisture content of 1.7 percent, a unit dry weight of 107.5 pcf, and a triaxial compressive strength of 3.64 tsf. The conglomerate primary material encountered in boring 3ST-4 was determined to have a moisture content ranging from 7.3 to 7.8 percent, a unit dry weight ranging from 136.3 to 136.9 pcf, and an unconfined compressive strength of 195 to 230 tsf.

4.3. Willis Creek. Samples of clays encountered within borings drilled along the Willis Creek channel alignment were determined to have liquid limits ranging from 35 to 44 percent, plastic limits ranging from 14 to 21 percent, moisture contents ranging from 7.1 to 19.7 percent; a unit dry weight of 112.7 pcf, and a triaxial compressive strength of 1.85 tsf were measured in boring 3ST-10. The clayey sand encountered in boring 3ST-7 was determined to have a liquid limit of 23 percent, a plastic limit of 15 percent, a moisture content of 16.3 percent, a unit dry weight of 118.4 pcf, and a triaxial compressive strength of 0.73 tsf. The shale primary material was determined to have liquid limits ranging from 55 to 63 percent, plastic limits ranging from 20 to 25 percent, moisture contents ranging from 12.3 to 27.2 percent, unit dry weights ranging from 106.9 to 114.2 pcf, and unconfined compressive strengths ranging from 0.64 to 5.86 tsf. Samples of the limestone were not collected for testing.

5. Discussion and Recommendations.

5.1. Slope Stability Analysis.

5.1.1. General. The proposed 1V:3.5H modified channel slope along Willis Creek was analyzed for stability at the locations of boring 3ST-7 and 3ST-9 (approximate channel stations 44+00 and 81+00, respectively) using the UTEXAS3 slope stability analysis computer program. The slopes were analyzed for conventional shear, under both unconsolidated-undrained (Q-test) and consolidated-drained (direct shear/S-test) conditions, using Spencer's Procedure, assuming a wedge failure plane. Slope stability analyses were performed at each location for both existing and modified channel conditions. Locations along Willis Creek at which limestone outcropped at a shallow depth were not considered for analysis, under the assumption that slope stability would not be a potential concern at these locations. No slope stability analyses were performed along the Adams Slough diversion channel alignment.

5.1.2. Boring 3ST-7 Location. The location of 3ST-7 was selected for slope stability analysis due to the variety of interbedded alluvial materials overlying the shale primary (refer to Plate F-12). Also, the overburden materials are comparatively thick (11.8 feet) above the shale primary. The existing and modified channel slopes at the location of boring 3ST-7 were analyzed for failure planes at three different depths: shallow (failure occurring at the clay/sand layer interface, above the static water table), intermediate (failure occurring at the gravel/shale interface, within the static water table), and deep (within the shale). Slope stability was determined to decrease with depth of failure plane in both the natural slope condition and the cut (modified) channel slope condition. Q-test factors of safety ranged from 10.473 to 4.041 for the natural slope, and from 4.867 to 4.491 for the cut slope. S-test factors of safety ranged from 10.473 to 3.875 for the natural slope, and from 3.077 to 2.964 for the cut slope.

5.1.3. Boring 3ST-9 Location. The location of boring 3ST-9 was selected for slope stability since the overburden material (gravel) overlying the shale is comparatively thin (approximately 2 feet thick), and therefore an opposite situation from the boring 3ST-7 location. Existing and modified slopes were analyzed at the location of boring 3ST-9 assuming failure within the shale primary. The factor of safety for the natural slope was determined to be 7.203, and the factor of safety for the cut (modified) slope was determined to be 4.678.

5.1.4. Slope Stability Analysis - Conclusions. The slope stability analyses performed at the locations of borings 3ST-7 and 3ST-9, selected as representative sections along Willis Creek, indicate that the proposed 1V:3.5H channel slopes should be stable at these locations.

5.2. Excavation. Approximately 250,000 cubic yards of material will be excavated for construction of the proposed channel modification along Willis Creek. Based on the materials encountered within the test holes, it is estimated that approximately 50% of the excavation along the Willis Creek channel alignment will be in rock (shale and/or limestone). Up to 50% of this excavation (up to 25% of the total excavation) may be in limestone hard enough to require rippers or jackhammers to construct the modified channel slopes to the recommended design configuration. It is anticipated that excavation in the shale may be accomplished using scrapers, as with soil excavation.

5.3. Care of Water During Construction. Willis Creek typically contains a small amount of flowing water, and water-bearing and pervious materials will be encountered during construction. Therefore construction cost estimates should include contingencies for construction dewatering, as well as diversion of surface and creek flow during construction.

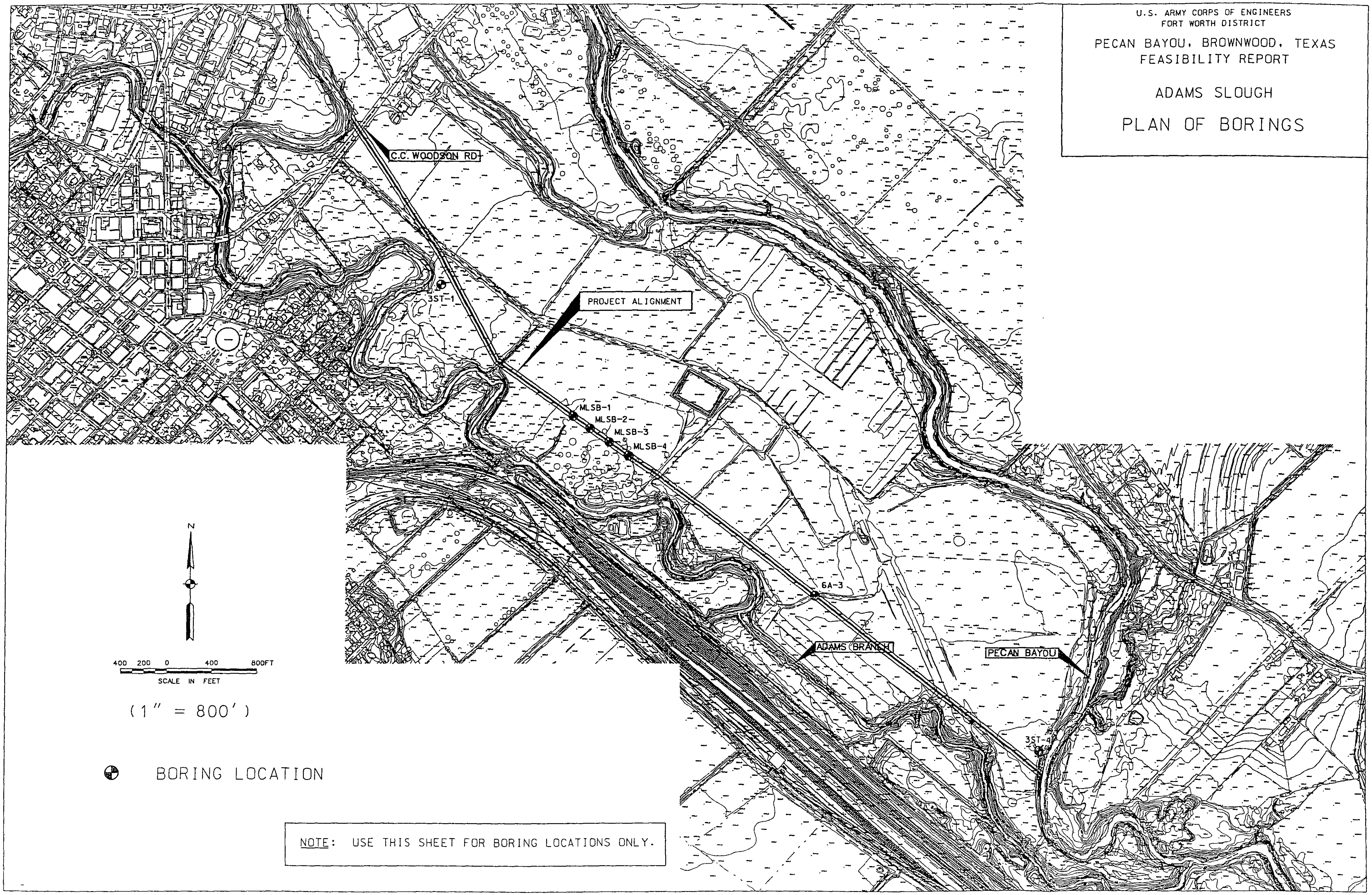
6. Conclusions. The project as proposed is geotechnically feasible. However, as previously stated, excavation within the limestone along Willis Creek may be difficult, requiring rippers or other specialized rock excavation equipment. It is recommended that additional borings be drilled along the channel alignment prior to construction to further define the amount of limestone anticipated for excavation quantity estimation purposes.

U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT

PECAN BAYOU, BROWNWOOD, TEXAS FEASIBILITY REPORT

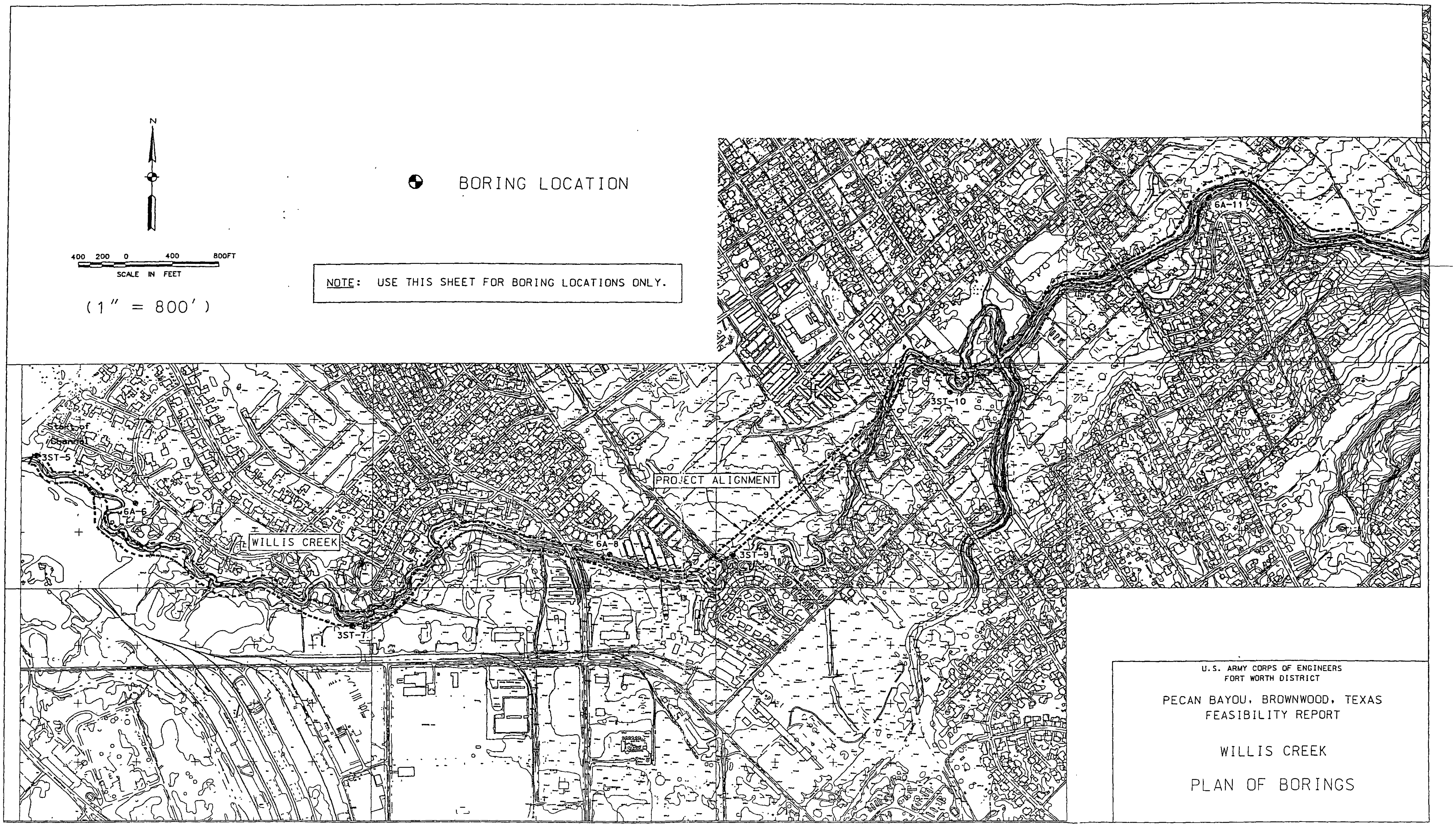
ADAMS SLOUGH

PLAN OF BORINGS



● BORING LOCATION

NOTE: USE THIS SHEET FOR BORING LOCATIONS ONLY.



U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT

PECAN BAYOU, BROWNWOOD, TEXAS
FEASIBILITY REPORT

WILLIS CREEK

PLAN OF BORINGS

Hole No. 3ST-1

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 3ST-1
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN -
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 20.0'
10. SIZE AND TYPE OF BIT 3" SHELBY & 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 3
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER 24 HR. CHECK @ 16.5'.
16. DATE HOLE STARTED 27 MAR 00 COMPLETED 27 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		VISUAL	<u>0.0' TO 20.0'</u> <u>CLAY</u> <u>0.0' TO 10.0'</u> - MEDIUM PLASTICITY, HARD, DRY, DARK BROWN TO BROWN, SILTY, SLIGHTLY SANDY, CALCAREOUS. <u>10.0' TO 20.0'</u> - AS ABOVE EXCEPT, LOW TO MEDIUM PLASTICITY, MOIST, MEDIUM STIFF TO SOFT, PENETROMETER - 1+, VERY SILTY AND SANDY.			1. <u>SHELBY TUBES:</u> 1. 5.0' TO 7.5' 2. 11.5' TO 14.0' 3. 17.5' TO 20.0'
14.2		▨			1	
	10	VISUAL				
21.0		▨			2	
		VISUAL				
23.7		▨			3	
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX

HOLE NO. 3ST-1

Hole No. 6A-3

DRILLING LOG | DIVISION SOUTHWESTERN | INSTALLATION FORT WORTH DISTRICT | SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 6A-3
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN -
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 20.0'
10. SIZE AND TYPE OF BIT 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO OF OVER-BURDEN SAMPLES TAKEN DISTURBED 4 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER DRY HOLE.
16. DATE HOLE STARTED 28 MAR 00 COMPLETED 28 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
11.8		▨	0.0' TO 20.0' CLAY - MEDIUM TO HIGH PLASTICITY, HARD AND DRY UNTIL 10.0', THEN MOIST AND MEDIUM STIFF, DARK BROWN TO BROWN, SILTY, SANDY, CALCAREOUS.		A	1. JAR SAMPLES: A. 0.0' TO 5.0' B. 5.0' TO 10.0' C. 10.0' TO 15.0' D. 15.0' TO 20.0'
21.7		▨			B	
	10	▨				
19.8		▨			C	
22.6		▨			D	
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX | HOLE NO. 6A-3

Hole No. 3ST-4

DRILLING LOG

DIVISION SOUTHWESTERN

INSTALLATION FORT WORTH DISTRICT

SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) 3ST-4
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 31.0'
8. DEPTH DRILLED INTO ROCK 9.0'
9. TOTAL DEPTH OF HOLE 40.0'
10. SIZE AND TYPE OF BIT SEE REMARKS NO. 1
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 4
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER 24 HR. CHECK @ 26.0'.
16. DATE HOLE STARTED 20 MAR 00 COMPLETED 22 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 85 %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

CLASSIFICATION OF MATERIALS (Description) d

0.0' TO 16.0'

CLAY

0.0' TO 6.0' - HIGH PLASTICITY, HARD, DRY, DARK BROWN, SILTY, SLIGHTLY SANDY.

6.0' TO 10.5' - AS ABOVE, EXCEPT BROWN, CALCAREOUS.

10.5' TO 16.0' - AS ABOVE, EXCEPT MEDIUM PLASTICITY, SLIGHTLY MOIST AND INCREASED SAND CONTENT.

16.0' TO 21.5'

SAND - MOSTLY FINE, BUT NUMEROUS COARSE TO FINE ZONES, DRY, SILTY, ROOTS, RED YELLOW TO LIGHT BROWN, CALCAREOUS, GRAVELLY AFTER 19.5' UP TO 1 1/2", CALCAREOUS.

21.5' TO 31.0'

GRAVEL/COBBLE - COARSE TO FINE UP TO 5" FROM HOLE, SLIGHTLY DAMP TO WET, VERY DENSE BY 25.0', SOME CEMENTATION, BROWN TO LIGHT BROWN, CALCAREOUS.

31.0' TO 40.0'

CONGLOMERATE - NO APPARENT WEATHERING, LIGHT GRAY, HARD/VERY HARD (ROCK CLASSIFICATION), MODERATELY TO WELL CEMENTED, MOSTLY ANGULAR CLASTS, MASSIVE, ARENACEOUS W/ARGILLACEOUS CLASTS AND SEAMS.

REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

1. DRILLING:

0.0' TO 27.0' - 8" AUGER AND 3" SHELBY PUSHES, CAVING GRAVELS AND SAND FROM 21.0', SET 27.0' OF 8" CASING,

27.0' TO 33.0' - 7 7/8" ROCKBIT, SOME WATER LOSS DURING DRILLING,

33.0' TO 40.0' - 4" DIAMOND CORE,

BAILED HOLE TO 32.0'.

HOLE OPEN TO 33.0' @ 24 HR. CHECK.

2. SHELBY TUBES:

1. 1.0' TO 3.0'
2. 8.0' TO 10.0'
3. 11.0' TO 13.0'
4. 18.0' TO 20.0'

3. CARTON SAMPLES:

C-1. 33.0' TO 34.0'

C-2. 38.0' TO 39.0'

% MOISTURE CONTENT a	DEPTH b	LEGEND c	% CORE RECOVERY e	BOX OR SAMPLE NO. f
		VISUAL		
13.6		▨		1
		VISUAL		
16.2	10	▨		2
		VISUAL		
12.0		▨		3
		VISUAL		
1.7	20	▥		4
	30	VISUAL		
7.8			LOST 1'	C-1
			LOST 1'	
7.3	40			C-2

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PROJECT - BROWNWOOD, TX

HOLE NO. 3ST-4

Hole No. MLSB-1

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT ADAMS BRANCH, BROWNWOOD, TX
2. LOCATION (Coordinates or Station) 250' N36°W FROM MLSB-2.
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) MLSB-1
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN -
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 12.0'
10. SIZE AND TYPE OF BIT SEE REMARKS NO. 1.
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO OF OVER-BURDEN SAMPLES TAKEN DISTURBED 1 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER DRY HOLE.
16. DATE HOLE STARTED 23 MAR 00 COMPLETED 23 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			<u>0.0' TO 9.6'</u> <u>FILL</u> - ONE FOOT OF A LOW PLASTIC, STIFF, DRY, BROWN, SANDY AND SILTY <u>CLAY</u> OVER A MUNICIPAL AND INDUSTRIAL DUMP W/GLASS, TREATED LUMBER, PLASTIC MIXED W/SAND AND CLAY, SEWER ODOR AFTER 5.0', DRY TILL 5.0', THEN MOIST, MOSTLY BLACK APPEARANCE WITH WHITE SHEETROCK MATERIAL. <u>9.6' TO 12.0'</u> <u>CLAY</u> - MEDIUM/LOW PLASTICITY, SOFT, MOIST TO VERY MOIST, GRAY-BROWN, SILTY, SANDY TO VERY SANDY.			1. <u>DRILLING:</u> 0.0' TO 10.0' - 8" AUGER, 10.0' TO 12.0' - 3" SHELBY. 2. <u>SAMPLES:</u> SAMPLED FROM 10.0' TO 12.0' FOR PH, TCLP: VOL. ORG, SEMI-VOL. ORGANICS, PESTICIDES, METALS. QA & QC ALSO TAKEN AND DESIGNATED AS MLSB-10. ALL LEL READS ZERO.
	10				1	
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX

HOLE NO MLSB-1

Hole No. MLSB-2

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT ADAMS BRANCH, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)* 250' N35° W FROM MLSB-3.
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* MLSB-2
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN -
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 12.0'
10. SIZE AND TYPE OF BIT 8" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 1 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER DRY HOLE.
16. DATE HOLE STARTED 22 MAR 00 COMPLETED 22 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			<u>0.0' TO 12.0'</u> <u>CLAY</u> - MEDIUM/LOW PLASTICITY, MEDIUM STIFF TO STIFF, DRY TO SLIGHTLY MOIST, DARK BROWN/BROWN, SILTY, SANDY.		1	1. <u>SAMPLES:</u> SAMPLED FROM 0.0' TO 12.0' AS COMPOSITE FOR TOTAL METALS, SEMI-VOL. ORGAN, VOL. ORG, PESTICIDES, HERBICIDE AND TCLP: METALS, VOL. ORG, SEMI-VOL. ORG, HERB, PEST.
	10					
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX HOLE NO MLSB-2

Hole No. MLSB-3

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT ADAMS BRANCH, BROWNWOOD, TX	10. SIZE AND TYPE OF BIT 8" AUGER.
2. LOCATION *(Coordinates or Station)* 265' N132°W FROM LAYOUT STAKE.	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
4. HOLE NO. *(As shown on drawing title and file number)* MLSB-3	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED 1 — UNDISTURBED 0
5. NAME OF DRILLER SALIK	14. TOTAL NUMBER CORE BOXES 0
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER DRY HOLE.
7. THICKNESS OF OVERBURDEN -	16. DATE HOLE — STARTED 22 MAR 00 — COMPLETED 22 MAR 00
8. DEPTH DRILLED INTO ROCK -	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE 12.0'	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			<u>0.0' TO 12.0'</u> <u>CLAY</u> - MEDIUM/LOW PLASTICITY, MEDIUM STIFF, SLIGHTLY MOIST, DARK BROWN, SILTY, DRY AND VERY STIFF FROM 3.0' TO 9.0', WHERE SLIGHTLY MOIST AGAIN.		1	1. <u>SAMPLES:</u> SAMPLED FROM 0.0' TO 12.0' AS COMPOSITE FOR TCLP: HERBICIDE, PESTICIDE, VOL. ORG. SEMI-VOL. ORGANICS, METALS, AND TOTAL METALS, PESTICIDES, HERBICIDES, SEMI-VOL. ORG., VOL. ORGANICS.
	10					
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX — HOLE NO MLSB-3

PLATE F-8

Hole No. MLSB-4

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1 PROJECT ADAMS BRANCH, BROWNWOOD, TX

2. LOCATION *(Coordinates or Station)* 250' N147°E FROM MLSB-3.

3. DRILLING AGENCY USCE

4. HOLE NO. *(As shown on drawing title and file number)* MLSB-4

5. NAME OF DRILLER SALIK

6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.

7. THICKNESS OF OVERBURDEN -

8. DEPTH DRILLED INTO ROCK -

9. TOTAL DEPTH OF HOLE 12.0'

10. SIZE AND TYPE OF BIT 8" AUGER & 3" SHELBY.

11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*

12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 1 UNDISTURBED 0

14. TOTAL NUMBER CORE BOXES 0

15. ELEVATION GROUND WATER DRY HOLE.

16. DATE HOLE STARTED 22 MAR 00 COMPLETED 22 MAR 00

17. ELEVATION TOP OF HOLE

18. TOTAL CORE RECOVERY FOR BORING %

19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			0.0' TO 2.8' CLAY - FILL, MEDIUM/LOW PLASTICITY, MEDIUM STIFF, DRY, RED BROWN/ BROWN, SANDY AND SILTY. 2.8' TO 9.6' FILL - GLASS, PLASTIC, AND WOOD, ETC., MOSTLY BLACK COLOR, SEWER ODOR FROM 5.0' TO 10.0'. 9.6' TO 12.0' CLAY - MEDIUM PLASTICITY, SOFT, MOIST, BROWN, SANDY, SILTY.			1. SAMPLES: SAMPLED FROM 10.0' TO 11.0' FOR TCLP: SEMI-VOL. ORGANICS, VOL. ORGANIC METALS, HERBICIDES AND PESTICIDES AS WELL AS PH. LEL READS UP TO 1 FROM 5 TO 10'.
	10				1	
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX

HOLE NO MLSB-4

PLATE F-9

Hole No. 3ST-5

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 3ST-5
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 2.5'
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 2.5'
10. SIZE AND TYPE OF BIT 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER DRY HOLE.
16. DATE HOLE: STARTED 28 MAR 00; COMPLETED 28 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		VISUAL	0.0' TO 2.5' CLAY - LOW PLASTICITY, HARD, DRY, RED, SILTY AND SANDY. - REFUSAL - LIMESTONE			
	10					
	20					
	30					
	40					

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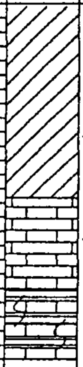
PROJECT BROWNWOOD, TX — HOLE NO. 3ST-5

Hole No. 6A-6

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO *(As shown on drawing title and file number)* 6A-6
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 5.5'
8. DEPTH DRILLED INTO ROCK 4.5'
9. TOTAL DEPTH OF HOLE 10.0'
10. SIZE AND TYPE OF BIT 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED 1 — UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER DRY HOLE.
16. DATE HOLE — STARTED 28 MAR 00 — COMPLETED 28 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
8.7			<u>0.0' TO 5.5'</u> <u>CLAY</u> - MEDIUM PLASTICITY, HARD, DRY, DARK BROWN TO BROWN, VERY SILTY, SANDY.		A	1. <u>JAR SAMPLE:</u> A. 0.0' TO 5.5'
			<u>5.5' TO 8.0'</u> <u>LIMESTONE</u> - NO APPARENT WEATHERING, JOINTED, GRAY-WHITE, VERY HARD AND WELL CEMENTED.			
			<u>8.0' TO 10.0'</u> <u>SHALE & LIMESTONE</u> - INTERBEDDED, WEATHERED SHALE.			
			- REFUSAL @ 10.0' - <u>LIMESTONE</u>			
	10					
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX — HOLE NO 6A-6

Hole No. 3ST-7

DRILLING LOG | DIVISION SOUTHWESTERN | INSTALLATION FORT WORTH DISTRICT | SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 3ST-7
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 11.8'
8. DEPTH DRILLED INTO ROCK 8.2'
9. TOTAL DEPTH OF HOLE 20.0'
10. SIZE AND TYPE OF BIT 6" AUGER & 3" SHELBY.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 0 UNDISTURBED 1
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER WATER @ 8.0'.
16. DATE HOLE STARTED 28 MAR 00 COMPLETED 28 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
			<u>0.0' TO 2.9'</u> <u>SAND</u> - COARSE TO FINE, DRY, LIGHT BROWN, VERY SILTY, GRAVELLY TO 1" DIA.			<u>NOTE:</u> CAVING GRAVELS. 1. <u>SHELBY SAMPLES:</u> 1. 7.0' TO 8.3' - REFUSAL @ 8.3'. 2. 12.0' TO 13.5' CAVING GRAVELS.
		VISUAL	<u>2.9' TO 7.0'</u> <u>CLAY</u> - MEDIUM PLASTICITY, MEDIUM STIFF, MOIST, SILTY, DARK BROWN TO BROWN, SLIGHTLY SANDY, GRAVELLY TO 2.5" DIA. W/SEAM @ 4.9' TO 5.1'.			
16.3		▨	<u>7.0' TO 8.0'</u> <u>SAND</u> - MOIST, LIGHT BROWN, CLAYEY.		1	
	10	VISUAL	<u>8.0' TO 11.8'</u> <u>GRAVEL</u> - COARSE TO FINE UP TO 2.5" DIA., WET, STRONG BROWN, VERY SANDY, CLAYEY.			
27.2		☰	<u>11.8' TO 20.0'</u> <u>SHALE</u> - WEATHERED YELLOW BROWN INTERBEDDED WITH UNWEATHERED DARK GRAY UNTIL 14.0', THEN ESSENTIALLY UNWEATHERED TO T.D., VERY SOFT/SOFT (ROCK CLASS.), SILTY, DRY, MASSIVE, BLOCKY, A FEW THIN, RED, HARD AND CEMENTED LIMONITE SEAMS/LENSES SCATTERED AFTER 14'.		2	
	20					
	30					
	40					

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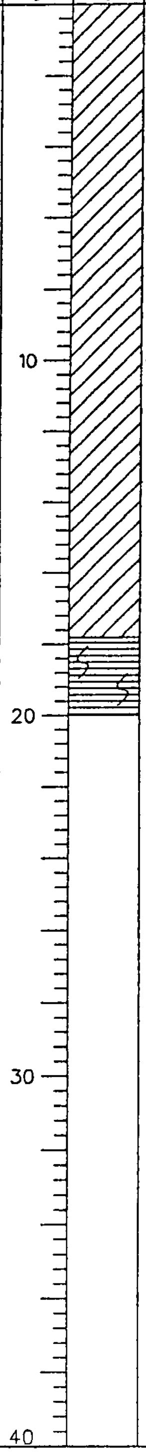
PROJECT BROWNWOOD, TX | HOLE NO 3ST-7

Hole No. 6A-8

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 6A-8
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 17.8'
8. DEPTH DRILLED INTO ROCK 2.2'
9. TOTAL DEPTH OF HOLE 20.0'
10. SIZE AND TYPE OF BIT 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED 4 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER WATER @ 12.0'.
16. DATE HOLE STARTED 27 MAR 00 COMPLETED 27 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

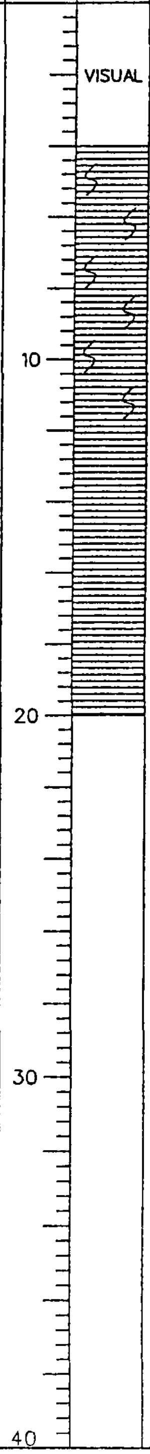


% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
9.8			<u>0.0' TO 17.8'</u> <u>CLAY</u> <u>4.6' TO 9.6'</u> - MEDIUM PLASTICITY, STIFF, SLIGHTLY MOIST, BROWN, VERY SILTY, SANDY, CALCAREOUS. <u>9.6' TO 13.5'</u> - MEDIUM PLASTICITY, MEDIUM STIFF, MOIST, BROWN, SANDY/SILTY, CALCAREOUS. <u>13.5' TO 17.8'</u> - MEDIUM PLASTICITY, MEDIUM STIFF, MOIST, LIGHT GRAY AND YELLOW BROWN, VERY SANDY AND SILTY, GRAVELLY WITH GRAVEL SEAMS, CALCAREOUS. <u>17.8' TO 20.0'</u> <u>SHALE</u> - WEATHERED, YELLOW BROWN AND SOFT (ROCK CLASS.), DRY, SILTY, CALCAREOUS.		A	1. <u>JAR SAMPLES:</u> A. 0.0' TO 4.6' B. 4.6' TO 9.6' C. 9.6' TO 13.5' D. 13.5' TO 17.8' E. 17.8' TO 20.0' OPEN TO 12.5' AFTER 24 HRS.
13.9					B	
19.7					C	
17.9					D	
					E	

Hole No. 3ST-9

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS
1. PROJECT PECAN BAYOU, BROWNWOOD, TX		10. SIZE AND TYPE OF BIT 6" AUGER & 3" SHELBY.	
2. LOCATION *(Coordinates or Station)*		11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*	
3. DRILLING AGENCY USCE		12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500	
4. HOLE NO. *(As shown on drawing title and file number)*	3ST-9	13. TOTAL NO OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 0 UNDISTURBED 0
5. NAME OF DRILLER SALIK		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.		15. ELEVATION GROUND WATER DRY HOLE.	
7. THICKNESS OF OVERBURDEN	2.0'	16. DATE HOLE	STARTED 28 MAR 00 COMPLETED 28 MAR 00
8. DEPTH DRILLED INTO ROCK	18.0'	17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE	20.0'	18. TOTAL CORE RECOVERY FOR BORING	%
		19. SIGNATURE OF INSPECTOR ROBERT McVEY	

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g



<u>0.0' TO 2.0'</u>

<u>GRAVEL</u> - COARSE TO FINE UP TO 1 1/2" DIA., INTERBEDDED WITH <u>SAND</u> SEAMS, DRY, BROWN, VERY SANDY/SILTY.

<u>2.0' TO 20.0'</u>

<u>SHALE</u>

<u>2.0' TO 11.8'</u> - WEATHERED, LIGHT OLIVE, YELLOW BROWN, AND LIGHT GRAY, DRY, SILTY AND SANDY, MASSIVE, BLOCKY, SOFT TO MEDIUM HARD ZONES (ROCK CLASS.), LIMY, SOME LOCAL CEMENTATION.

<u>11.8' TO 20.0'</u> - UNWEATHERED, DARK GRAY TO OLIVE WITH RED AFTER 16.0', SILT SEAMS, SOFT (ROCK CLASS.), MASSIVE, A FEW HARD, THIN, CEMENTED, RED, LIMONITE SEAMS (LESS THAN 0.2' THICK), CALCAREOUS.

Box or sample no.: S-1 (5.0' to 7.5'), S-2 (11.5' to 14.0')

1. <u>SHELBY SAMPLES:</u>
   1. 5.0' TO 7.5'
   2. 11.5' TO 14.0'

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PROJECT BROWNWOOD, TX | HOLE NO 3ST-9

Hole No. 3ST-10

DRILLING LOG
DIVISION SOUTHWESTERN
INSTALLATION FORT WORTH DISTRICT
SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 3ST-10
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN -
8. DEPTH DRILLED INTO ROCK -
9. TOTAL DEPTH OF HOLE 20.0'
10. SIZE AND TYPE OF BIT 6" AUGER & 3" SHELBY.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED 1 — UNDISTURBED 1
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER ***24 HR. @ 13.3'.
16. DATE HOLE — STARTED 27 MAR 00 — COMPLETED 27 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOV-ERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		VISUAL	<u>0.0' TO 7.0'</u> <u>SILT/SAND</u> - FINE WITH NO/LOW PLASTICITY, DRY, DARK BROWN/ BROWN, VERY CLAYEY (LOW TO MEDIUM PLASTICITY) W/SEAMS, CALCAREOUS.			1. <u>SHELBY SAMPLE:</u> PUSH FROM 5.0' TO 7.5' WAS A REFUSAL (JARRED) 1. 11.5' TO 14.0' PUSH @ 17.5' REFUSED.
7.1		▨	<u>7.0' TO 10.0'</u> <u>GRAVEL/SAND</u> - COARSE TO FINE, BEDDED, MEDIUM DENSE TO DENSE, DRY, BROWN, VERY SILTY/CLAYEY.		A	2. <u>JAR SAMPLE:</u> A. 5.0' TO 5.5' ***OPEN TO 13.7' AFTER 24 HRS.
	10	VISUAL	<u>10.0' TO 18.0'</u> <u>CLAY</u> - MEDIUM PLASTICITY, MEDIUM STIFF, MOIST, LIGHT BROWN AND YELLOW BROWN, VERY SILTY, SANDY, SANDY LIME NODULES, GRAVELLY, CALCAREOUS.			
17.9		▨	<u>18.0' TO 20.0'</u> <u>GRAVEL/COBBLE</u> - COARSE TO FINE UP TO 5" DIA. FROM HOLE, WET, STRONG BROWN, SANDY, CLAYEY, CALCAREOUS.		1	
		VISUAL				
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX
HOLE NO. 3ST-10

Hole No. 6A-11

DRILLING LOG	DIVISION SOUTHWESTERN	INSTALLATION FORT WORTH DISTRICT	SHEET 1 OF 1 SHEETS

1. PROJECT PECAN BAYOU, BROWNWOOD, TX
2. LOCATION *(Coordinates or Station)*
3. DRILLING AGENCY USCE
4. HOLE NO. *(As shown on drawing title and file number)* 6A-11
5. NAME OF DRILLER SALIK
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 3.9'
8. DEPTH DRILLED INTO ROCK 1.6'
9. TOTAL DEPTH OF HOLE 5.5'
10. SIZE AND TYPE OF BIT 6" AUGER.
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED 0 | UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER WATER @ 3.5'.
16. DATE HOLE | STARTED 27 MAR 00 | COMPLETED 27 MAR 00
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR ROBERT McVEY

% MOISTURE CONTENT a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
		VISUAL	<u>0.0' TO 3.9'</u> <u>GRAVEL</u> - COARSE TO FINE UP TO 2.5" DIA., DRY UNTIL 3.5', THEN WET, BROWN, VERY SANDY AND CLAYEY.			<u>NOTE:</u> OUTCROPS IN CREEK BED OF LIMESTONE. COULD BE RE-CEMENTED LIMESTONE.
			<u>3.9' TO 5.5'</u> <u>LIMESTONE</u> - WEATHER STAINED, YELLOW BROWN AND LIGHT GRAY-WHITE, VERY HARD AND WELL CEMENTED, JOINTED, ARGILLACEOUS AND ARENACEOUS, NODULAR APPEARANCE IN OUTCROP.			
	10					
	20					
	30					
	40					

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PROJECT BROWNWOOD, TX | HOLE NO 6A-11

SUB-APPENDIX G

ENVIRONMENTAL RESOURCES

SUB-APPENDIX G

ENVIRONMENTAL RESOURCES

ENVIRONMENTAL SETTING

GENERAL

The study area lies on the western boundary of what is known as the Cross Timbers and Prairies Ecological Area of Texas. Total annual precipitation is approximately 27 inches, with an average temperature of 47 degrees Fahrenheit in winter and 83 degrees in the summer. The terrain ranges from gently rolling hills to large expanses of sloping, flat areas. Geologically, the area lies within outcrops of Pennsylvanian, Permian, and lower Cretaceous strata which are primarily sedimentary in origin. Soils in the area belong to the Frio-Sunev-Winter series that is characterized as nearly level to gently sloping, deep, loamy soils over loamy and clayey alluvium. Pecan Bayou is the primary drainage through the general study area and is a tributary of the Colorado River. Willis Creek is a tributary of Pecan Bayou

LAND USE

Outside of the urban centers, land use is dispersed with several small homesteads and/or large homesteads and a few hunting and fishing camps located along the bayou. Ranches and small farms are generally located in the hilly uplands surrounding Pecan Bayou. Cultivated cover crops or row crops, including oats, wheat, sorghum, peanuts, rye, barley, vetch, alfalfa, and millet are also located throughout the study area. Grassland, associated with crop rotation and cattle grazing is another land use within the study area. Livestock production appears to consist mainly of cow-calf operations or growing sheep for production of wool and lambs. Angora goats, swine, horses, and poultry are also raised throughout the county.

Areas surrounding Willis Creek along the upper reaches are predominately residential. Other tracts of land surrounding the upper reaches of Willis Creek include an old military base, forest, and open fields. Most of the lower reach of Willis Creek is deeply incised and surrounded by open range, old field, or riparian forest. The City water treatment plant is also located on the lower reach just upstream from the confluence of Willis Creek and Pecan Bayou.

AIR QUALITY

Brownwood is located in air quality Region 3 (Abilene) of the Texas Natural Resource Conservation Commission (TNRCC). Air quality is not continuously monitored in this area so the existing air quality is not known. Since Brownwood is located outside any major metropolitan area and has no know major stationary emitters of air pollutants, air quality is good to moderate quality.

WATER QUALITY

The watershed in the study area is divided into six segments by the State of Texas for water quality inventories. These segments start at the confluence of Pecan Bayou and the Colorado River and proceed upstream through and above Lake Brownwood. The segments are summarized as follows. Segment 1417, Lower Pecan Bayou, covers the area from the confluence of Pecan Bayou and the Colorado River in Mills County to a point immediately upstream of the confluence of Mackinally Creek in Brown County. The segment is summarized as: Average phosphorous levels are elevated in this segment, and the segment is influenced by upstream segment 1431. Segment 1431, Mid-Pecan Bayou, covers a point immediately upstream of Willis Creek in Brown County. The segment is summarized as: Elevated fecal coliform levels have been documented in this segment. Average inorganic nitrogen and phosphorous levels are persistently elevated. This segment is influenced by the City of Brownwood wastewater treatment facility. Segment 1432, Upper Pecan Bayou, covers from a point immediately upstream of the confluence of Willis Creek to Lake Brownwood Dam. This segment is summarized as: No water quality problems in this segment. Segment 1418, Lake Brownwood, covers from Lake Brownwood Dam to a point 100 meters upstream of FM 2559 in Brown County. The segment is summarized as: No water quality problems in this segment. Segment 1420, Pecan Bayou above Lake Brownwood, covers from a point 100 meters upstream of FM 2559 to the confluence of the North Prong Pecan Bayou and the South Prong Pecan Bayou in Callahan County. This segment is summarized as: an intermittent stream with perennial pools. Willis Creek is not identified as a separate stream segment and has no water quality surveys documented on record.

AQUATIC RESOURCES

Pecan Bayou

The character and composition of the aquatic resources of Pecan Bayou have been influenced by prior projects such as the construction of Lake Brownwood and the two overflow spillways near the City. The fishery and other aquatic resources have been altered through past projects along the Bayou. Below U.S. 67, large concentration of rough fish such as gar and carp occur in deep pools, and green sunfish, largemouth bass, and catfish (bullhead, channel, and flathead) are abundant throughout the system. A list of fish species known to occur in Pecan Bayou and immediate tributaries is presented in Appendix Table 1. A recent survey documenting the populations of fish or other aquatic organisms inhabiting the Pecan Bayou system is not available.

Pecan Bayou varies in width from 40 to 60 feet and the water depth ranges from being very deep (>10 feet) to very shallow. Riffle, pool, and run complexes throughout the system are abundant. The banks of the bayou are heavily eroded in some areas, with tree roots and exposed bare soil. Slopes of the banks vary from moderate to extremely steep. Aquatic habitat in the bayou includes overhanging vegetation, dead fallen limbs and trees, animal burrows, root wads, undercut banks, limestone outcrops, and mixed sorted gravel beds.

Willis Creek

Willis Creek is a major tributary of Pecan Bayou. This tributary flows into Pecan Bayou just east of the city. Throughout most of the year, Willis Creek is a low gradient stream exhibiting low flow conditions. During storm events, water levels in the creek quickly rise and fall. Stream flows during these events are of extremely high velocity. The banks of Willis Creek are fairly unstable and highly erosive as evidenced by many areas of sloughing and undercutting. Consequently, many large fallen trees can be found throughout the system. Many homes, backyards, and stormwater drainage pipes in the upper reaches of Willis Creek appear to be threatened by erosion.

The stream morphology of Willis Creek is extremely variable. The composition of stream banks and bottom ranges from being solid limestone outcrops and unconsolidated boulders to clay and heavy deposits of silt. Riffle, pool, and run complexes are numerous. There are also many areas along the upper reaches of Willis Creek where residents have landscaped their backyards using pavers, stones, or concrete right into the stream. On a walking survey conducted by the Corps and the United State Fish and Wildlife Service there were 22 riffles, 22 runs and 27 pools identified in the Willis Creek study area. The riffles averaged approximately 53 feet in length, were about 7 feet width, and had a depth that was roughly 1 foot. The runs averaged approximately 95 feet in length, were about 8 feet wide, and had a depth that was about 1.5 feet. The pools identified were roughly 280 feet long, about 16 feet wide, and were about 4 feet deep. As for overall percentage composition of each of the morphologic features, pools dominated the distribution by providing slightly over 70% of the stream length, runs comprised about 19% of the stream length, and riffles made up the remaining 11% of the stream length. At least four man-made low water weirs exist and responsible for creating a significant amount of the pool habitat in the upper reaches of Willis Creek, also several or the residents have constructed bridges across the stream.

Aquatic habitat throughout Willis Creek is of high quality in the stretches of the creek that have not been improved. Aquatic habitat in this system includes root wads, overhanging vegetation, boulders and mixed sorted gravel beds, rock outcrops, undercut banks, and animal burrows. The composition of the fish and other aquatic organisms in Willis Creek has not been documented but probable would resemble those of the aquatic invertebrates and macroinvertebrates found in the adjacent Pecan Bayou.

A survey of the study area by Corps and United States Fish and Wildlife Service personnel indicated that there were no jurisdictional wetlands along Willis Creek.

TERRESTRIAL RESOURCES

Generally, the riparian woodlands that border Pecan Bayou and its tributaries contain tree and shrub species such as pecan, live and red oak, red mulberry, Chinaberry, American and cedar elm, buttonbush with interspersed fields of native and introduced grasses. Ground cover consists mainly of trumpet creeper, Virginia creeper, side oats gramma, poison ivy, coral berry, weeping love grass and coastal Bermudagrass. Riparian woodlands follow the bayou with hardwood forests, oak-mesquite woodlands, mesquite-shrub pastures, grasslands, and agricultural lands comprising the upper elevations.

Within most of the rural areas surrounding the bayou and Willis Creek, good habitat is provided for a wide range of terrestrial animal species. Game species are abundant within the study area and include white-tailed deer, turkey, bobwhite, eastern cottontail, squirrel, and many types of ducks. Non-game species present in the study area include passerine and non-passerine birds, beaver, opossum, armadillo, bobcat, skunk, mink, raccoon, and nutria. A listing of many of the terrestrial species including reptiles and amphibians, found within the study are presented in Table 1.

Predominate terrestrial habitat types that were identified within the Willis Creek study area consisted of “Old Field” and “Riparian Forest”. Old Field areas are primarily devoid of large woody vegetation such as mature trees. Old Field areas may contain light densities of scrub shrub vegetation such as mesquite or juniper and moderate to high concentrations of cultivated grasses such as Coastal Bermuda. Old Field areas generally have low wildlife habitat value, but are still an important component of the ecosystem that provide critical habitat for some smaller animals such as rodents. “Riparian Forests” are highly vegetated corridors within the immediate vicinity of the stream or waterbody. Vegetation within the riparian forest along Willis Creek include stands of pecan, live and red oak, hackberry, Chinaberry, greenbrier, wild grape, coralberry, American beautyberry, side oats gramma, and other plant species that provide wildlife habitat of exceptional value.

FEDERAL THREATENED AND ENDANGERED SPECIES

According to the United States Fish and Wildlife Service, the following species are listed as either threatened or endangered within the Pecan Bayou watershed. They are the threatened Concho Water Snake (*Nerodia paucimaculata*), Whooping Crane (*Grus americana*) and the endangered Black-capped vireo (*Vireo atricapillus).* No black-capped vireo habitat is known to occur along Pecan Bayou and the Concho Water Snake Recovery Plan (Fish and Wildlife Service 1993) indicates populations appear to be fairly continuous to about the FM 45 bridge upstream from the mouth of Pecan Bayou. However, no Concho water snakes have been found in Pecan Bayou study area.

STATE SPECIAL SPECIES AND CRITICAL HABITATS

According to the Texas Parks and Wildlife Department Endangered Resources Branch, the following species are listed as either threatened or endangered within Brown County. They are the American Peregrine Falcon (*Falco peregrinus anatum*), Artic Peregrine Falcon (*Falco peregrinus tundrius*), Whooping Crane (*Grus americana*), Interior Least Tern (*Sterna antillarum athalassos*), Concho Water Snake (*Nerodia paucimaculata*), Texas Horned Lizard (*Phrynosoma cornutum*), and Hill Country Wild-Mercury (*Argythamnia aphoroides*).

Table 1. Terrestrial and aquatic animal species that occur within the project study area of Brownwood, Texas.

Common Name	***Genus species***
BIRDS	
Game Birds	
green-winged teal	*Anas crecca*
mallard	*Anas platyrhynchos*
wood duck	*Aix sponsa*
northern bobwhite	*Colinus virginianus*
wild turkey	*Meleagris gallopavo*
mourning dove	*Zenaida macroura*
Non-passerine Birds	
turkey vulture	*Cathartes aura*
black vulture	*Coragyps atratus*
Cooper's hawk	*Accipiter cooperii*
red-tailed hawk	*Buteo jamaicensis*
Swainson's hawk	*Buteo swainsoni*
American kestrel	*Falco sparverius*
great horned owl	*Bubo virginianus*
barred owl	*Strix varia*
great blue heron	*Ardea herodias*
little blue heron	*Egretta caerulea*
green heron	*Butorides striatus*
killdeer	*Charadrius vociferous*
least sandpiper	*Calidris minutilla*
yellow-billed cuckoo	*Coccyzus americanus*
greater roadrunner	*Geococcyx californianus*
common nighthawk	*Chordeiles minor*
chimney swift	*Chaetura pelagica*
belted kingfisher	*Ceryle alcyon*
red-bellied woodpecker	*Melanerpes carolinus*
hairy woodpecker	*Picoides villosus*
ruby-throated hummingbird	*Archilochus colubris*
Passerine Birds	
red-winged blackbird	*Agelaius phoeniceus*
northern cardinal	*Cardinalis cardinalis*
American goldfinch	*Carduelis psaltria*
American crow	*Corvus brachyrhynchos*
barn swallow	*Hirundo rustica*
cliff swallow	*Hirundo pyrrhonota*
loggerhead shrike	*Lanius ludovicianus*
scissor-tailed flycatcher	*Tryannus forficatus*
western kingbird	*Tyrannus verticalis*
eastern phoebe	*Sayornis phoebe*
northern mockingbird	*Mimus polyglottos*

Table 1 Continued.

brown-headed cowbird	*Molothrus ater*
painted bunting	*Passerina ciris*
purple martin	*Progne subis*
Carolina chickadee	*Parus carolinensis*
tufted titmouse	*Parus bicolor*
rufous-sided towhee	*Pipilo erythrophthalmus*
blue-gray gnatcatcher	*Quiscalus mexicanus*
great-tailed grackle	*Quiscalus mexicanus*
Bewick's wren	*Thryomanes bewickii*
Carolina wren	*Thryothorus ludovicianus*
American robin	*Turdus migratorius*
meadowlark	*Sturnella spp.*
Nashville warbler	*Vermivora ruficapilla*
white-eyed vireo	*Vireo griseus*
rufous-crowned sparrow	*Zonotrichia albicollis*

Introduced Exotic Birds

cattle egret	*Bubulcus ibis*
rock dove	*Columbia livia*
house sparrow	*Passer domesticus*
European starling	*Sturnus vulgarius*

MAMMALS

beaver	*Castor canadensis*
nine-banded armadillo	*Dasypus novemcinctus*
Virginia opossum	*Didelphis virginiana*
bobcat	*Lynx rufus*
striped skunk	*Mephitis mephitis*
mink	*Mustela vison*
nutria	*Myocastor coypus*
white-tailed deer	*Odocoileus virginianus*
raccoon	*Procyon lotor*
fox squirrel	*Sciurus niger*
rock squirrel	*Spermophilus variegates*
eastern cottontail	*Sylvilagus floridanus*

FISH

yellow bullhead catfish	*Ictalurus natalis*
channel catfish	*Ictalurus punctatus*
flathead catfish	*Plyodictus olivarus*
common carp	*Cyprinus carpio*
river carpsucker	*Carpoides carpio*
blackstripe topminnow	*Fundulus notatus*
mosquitofish	*Gambusia affinis*
spotted gar	*Lepisosteus oculatus*
bluegill	*Lepomis macrochirus*
green sunfish	*Lepomis cyanellus*
longear sunfish	*Lepomis megalotis*

Table 1 Continued.

largemouth bass	*Micropterus salmoides*
REPTILES	
Turtles	
red-eared slider	*Trachemys scripta*
Texas slider	*Chrysemys concinna texana*
Texas map turtle	*Graptemys versa*
Lizards	
Prairie-lined racerunner	*Cnemidophorus viridis*
Texas spiny lizard	*Sceloporus olivaceous*
Texas horned lizard	Phrynosoma cornutum
Snakes	
western diamondback rattlesnake	*Crotalus atrox*
blotched water snake	*Nerodia erythrogaster*
diamondback water snake	*Nerodia rhombifera*
AMPHIBIANS	
bullfrog	*Rana catesbeiana*
cricket frog	*Acris crepitans*

PLAN FORMULATION

FINAL ARRAY OF ALTERNATIVES

NO ACTION PLAN

FLOOD DAMAGE REDUCTION

Hydraulic Channel 10-ft Bottom Width

ENVIRONMENTAL IMPACTS

LAND USE

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit a Floodplain Management Plan (FPMP). Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be adversely impacted as a result of implementing this alternative.

AIR QUALITY

Construction activity associated with the implementation of this alternative would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the Texas Natural Resource Conservation Commission (TNRCC). Maintenance activities required for the hydraulic channel with a 10-ft bottom width alternative would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts to air quality through elimination of biogenic sources that remove regulated gaseous air pollutants.

WATER QUALITY

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem.

AQUATIC RESOURCES

Construction of a hydraulic channel with a 10-ft bottom width would adversely impact approximately 16,554 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. This avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species.

TERRESTRIAL RESOURCES

Construction of a hydraulic channel with a 10-ft bottom width would adversely impact plant and animal terrestrial resources inhabiting the approximately 7.7acres of old field habitat and 27.0 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat would be less effective in maintaining wildlife diversity than an intact riparian corridor.

FEDERAL THREATENED AND ENDANGERED SPECIES

Implementation of this alternative would result in no adverse impacts to any Federal threatened or endangered species.

STATE SPECIAL SPECIES AND CRITICAL HABITATS

Implementation of this alternative would result in no adverse impacts to any State of Texas listed threatened, endangered, or special species or critical habitats.

Hydraulic Channel 25-ft Bottom Width

ENVIRONMENTAL IMPACTS

LAND USE

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit a FPMP. Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be adversely impacted as a result of implementing this alternative.

AIR QUALITY

Construction activity associated with the implementation of this alternative would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the hydraulic channel with a 25-ft bottom width alternative would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

WATER QUALITY

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem.

AQUATIC RESOURCES

Construction of a hydraulic channel with a 25-ft bottom width would adversely impact approximately 16,554 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. This avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species.

TERRESTRIAL RESOURCES

Construction of a hydraulic channel with a 25-ft bottom width would adversely impact plant and animal terrestrial resources inhabiting the approximately 9.1 acres of old field habitat and 33.8 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat would be less effective in maintaining wildlife diversity than an intact riparian corridor.

FEDERAL THREATENED AND ENDANGERED SPECIES

Implementation of this alternative would result in no adverse impacts to any Federal threatened or endangered species.

STATE SPECIAL SPECIES AND CRITICAL HABITATS

Implementation of this alternative would result in no adverse impacts to any State of Texas listed threatened, endangered, or special species or critical habitats.

Hydraulic Channel 45-ft Bottom Width

ENVIRONMENTAL IMPACTS

LAND USE

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit a FPMP. Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be adversely impacted as a result of implementing this alternative.

AIR QUALITY

Construction activity associated with the implementation of this alternative would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the hydraulic channel with a 45-ft bottom width alternative would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

WATER QUALITY

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem.

AQUATIC RESOURCES

Construction of a hydraulic channel with a 45-ft bottom width would adversely impact approximately 16,554 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. This avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species.

TERRESTRIAL RESOURCES

Construction of a hydraulic channel with a 45-ft bottom width would adversely impact plant and animal terrestrial resources inhabiting the approximately 9.9 acres of old field habitat and 37.7 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat are less effective in maintaining wildlife diversity than an intact riparian corridor.

FEDERAL THREATENED AND ENDANGERED SPECIES

Implementation of this alternative would result in no adverse impacts to any Federal threatened or endangered species.

STATE SPECIAL SPECIES AND CRITICAL HABITATS

Implementation of this alternative would result in no adverse impacts to any State of Texas listed threatened, endangered, or special species or critical habitats.

Hydraulic Channel 60-ft Bottom Width

ENVIRONMENTAL IMPACTS

LAND USE

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit a FPMP. Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be adversely impacted as a result of implementing this alternative.

AIR QUALITY

Construction activity associated with the implementation of this alternative would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the hydraulic channel with a 60-ft bottom width alternative would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

WATER QUALITY

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem.

AQUATIC RESOURCES

Construction of a hydraulic channel with a 60-ft bottom width would adversely impact approximately 16,554 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. This avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species.

TERRESTRIAL RESOURCES

Construction of a hydraulic channel with a 60-ft bottom width would adversely impact plant and animal terrestrial resources inhabiting the approximately 13.8 acres of old field habitat and 39.6 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat would be less effective in maintaining wildlife diversity than an intact riparian corridor.

FEDERAL THREATENED AND ENDANGERED SPECIES

Implementation of this alternative would result in no adverse impacts to any Federal threatened or endangered species.

STATE SPECIAL SPECIES AND CRITICAL HABITATS

Implementation of this alternative would result in no adverse impacts to any State of Texas listed threatened, endangered, or special species or critical habitats.

RECOMMENDED PLAN

ENVIRONMENTAL IMPACTS

LAND USE

In accordance with Section 202(c) of the Water Resources Development Act of 1996, within one year of implementation of the proposed project, the City of Brownwood would be required to submit a FPMP. Measures in the FPMP would include restrictions on any business or residential development in the floodplain of Willis Creek. Under these restrictions, land use in the floodplain would not be further adversely impacted as a result of implementing the recommended plan.

AIR QUALITY

Construction activity associated with the implementation of the recommended would result in temporary adverse impacts to air quality from fugitive dust production, smoke, and construction vehicle emissions. There would be no stationary emitting sources and no on site storage of petroleum or petroleum based by-products to cause additional negative impacts to air quality. Disposal of cleared vegetation or other debris by burning during the construction would be allowed only as permitted by the TNRCC. Maintenance activities required for the recommended plan would contribute small amounts of additional mobile air emissions.

The reduction in tree canopy area and other perennial and annual vegetation from clearing activities for hydraulic channel construction would result in negative impacts through elimination of biogenic sources that remove regulated gaseous air pollutants.

WATER QUALITY

Implementation of this alternative would result in short- and long-term adverse impacts to the water quality of Willis Creek. Short-term impacts would result from the movement of construction vehicles associated with excavation and grading activities in and around the Willis Creek channel. These activities would generate suspended sediments in the water column and increase turbidity levels. Suspended sediments would shade and silt over oxygen producing phytoplankton and aquatic plants and suppress water dissolved oxygen levels. Long-term impacts to water quality would result from removal of vegetation in the riparian corridor surrounding Willis Creek. Removal of the Willis Creek tree canopy would reduce the amount of water shading and would cause increases in water temperatures. At a higher temperature, water is less capable of holding dissolved oxygen. Consequently, annual average dissolved oxygen concentrations in Willis Creek would be lower because of higher water temperatures. Removal of the other components of the Willis Creek riparian corridor would adversely compromise the ability of the riparian system to contribute organic nutrients to the stream ecosystem and adversely impact the riparian corridor's ability to filter out nutrients or noxious chemicals from the watershed. Implementation of a restrictive FPMP would moderate some of the adverse impacts resulting from the loss of the riparian corridor by limiting floodplain development and associated increases in the concentrations of nutrients or noxious chemicals that would enter the Willis Creek ecosystem. Additional adverse impacts to water quality would be minimized through the development and implementation of a National Pollution and Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan (SWPPP) that require provisions for corrective and implementable measures to prevent pollutants from entering Willis Creek during a storm event that would occur during and after construction activities. A non-maintenance herbaceous riparian corridor will be maintained a minimum of 5 ft from the edge of the base flow stream. In addition, a forested riparian corridor will also be established along the top of bank where impacted by the one-sided excavation. Specified limited access points at the top of channel, typically near major road crossings, will be required for channel maintenance vehicles.

Adverse impacts to water quality would be minimized through the development and implementation of a National Pollution and Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan (SWPPP) that require provisions for corrective and implementable measures to prevent pollutants from entering Willis Creek during a storm event that would occur during and after construction activities. This requirement is for project sites greater than 5 acres, including all temporary access roads, trailer sites, storage areas, and any other disturbed area associated with the project. The contractor would be required to complete a Notice of Intent (NOI) for Storm Water Discharges as required for an NPDES General Permit administered by the Environmental Protection Agency (EPA). The Contractor would also develop a detailed SWPPP within the guidelines of the COE's basic SWPPP and will provide drawings to accompany the SWPPP showing the locations of all stormwater controls. Stormwater controls entail both methods for temporary and permanent stabilization.

Temporary Measures to Minimize Short-term Adverse Impacts to Water Quality

Temporary stabilization activities would occur for all unpaved, graded and disturbed portions of the site when construction activities cease for 21 days or more and there is no requirement for permanent turfing. Temporary stabilization include structural and nonstructural measures. A nonstructural method for temporary stabilization would be to till the soil around Willis Creek to a depth of four inches, spread native prairie hay such as broomsedge, bluestem, little bluestem, big bluestem, switchgrass, and Indian grass, at a rate of 4000 pounds per acre, and anchor the mulch into place using a mulch anchoring machine equivalent to a disk harrow with cupped disks removed and replaced with straight rolling coulters spaced not more than eight inches apart. Structural stormwater controls would be used during temporary stabilization to prevent soil erosion where construction produces the potential for significant erosion damage, particularly where there is significant slope and at the boundaries of the project's unpaved and disturbed land. Some of the typical temporary structural stormwater controls that would be used to minimize sediment runoff include silt fences, staked hay bales, diversion dikes, excavated sediment traps, pipe slope drains, rock berm or check dams, log check dams, rock check dam, and sand bag berms. In feasibility, the level of detail of study detail makes it impractical to state specifically what measures would be used and where the stormwater controls would be placed, the following are the specific conditions under which each measure could be utilized:

Silt Fence – Silt fences shall be used for drainage areas of 1 acre or less with velocities of 0.5 FPS or less. The silt fences would not be constructed in tributaries or swales that lead into Willis Creek. The silt fences would be used primarily for perimeter control of overland flow to prevent sheet and rill erosion. Sediment would be removed from the silt fence when it accumulates to one-third the height of the fence. The silt fences would be securely fastened to each support post or to the backing, which is in turn attached to a fence post. See Figure 1.

Staked Hay Bales – Staked hay bales would be used for drainage areas of 1 acre or less with velocities of 0.5 FPS. The bales would not be used in tributaries or swales that lead into Willis Creek. The hay bales would be used primarily for perimeter control of overland flow to prevent sheet and rill erosion. The hay bales would be used where the effectiveness is required for less than 3 months, or the bales would be replaced every three months. Hay bales would be placed end to end with no caps between the bales. The accumulated sediment would be removed and disposed when it reaches a depth of 6". See Figure 2.

Diversion Dikes – Diversion dikes would be used to divert storm flows of 1 foot in depth or less, from Willis Creek. The side slopes of the diversion dikes would be 3:1 or flatter and the minimum width of the embankment at the crown would be 2 feet. Dike height would be a minimum of one foot greater than the flow depth for the 10-year event. Diversion dikes would be placed parallel to existing contours for perimeter control by diverting run-on water away from the disturbed area. See Figure 3.

Excavated Sediment Trap - An excavated sediment trap would be used in small drainage areas around Willis Creek of less than 1 acre, where overflow capacity is needed and in areas of heavy flow, 0.5 CFS or greater. The drainage area would be fairly flat with slopes of 5% or less. Washed gravel (3-5 inches in diameter) would be used to a depth of at least 1 foot. The recommended volume of sediment trap is 35 cubic yard per acre disturbed. Sediment would be removed from the trap when it accumulates to half the height of the filler stone. Weep holes would be filled with grout prior to backfilling of storage. See Figure 4.

Pipe Slope Drain – A pipe slope drain would be recommended for drainage areas around Willis Creek up to 10 acres. The pipe inlet and outlet would be stabilized. A flared end section would be used at the entrance of the pipe and soil around the pipe fully compacted. The outlet would enter into a 12inch thick bed of riprap. Diversion dike height on the drain would be a minimum of one foot greater than the flow depth for the 10-year event. See Figure 5.

Rock Berm or Check Dam – Check dams would be installed in steeply sloped swales or in swales sloping into Willis Creek where adequate vegetation cannot be established (not streams). Open graded rock, 4-8 inches in diameter would be used in the check dams. The dams would be secured with a woven wire sheathing having maximum 1 inch opening and minimum wire diameter of 20 gauge. Check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it accumulates to one-third of the height of the berm. See Figure 6.

Log Check Dam – Log check dams would be installed in steeply sloped swales, or in swales sloping into Willis Creek where adequate vegetation cannot be established (not streams). The logs used would be from 6 to 8 inches in diameter. Log check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it reaches a height of one half the original dam height. See Figure 7.

Rock Check Dam – Rock check dams would be installed around Willis Creek in drainage areas of 2 acres or less. Rock check dams would be constructed with 5 to 15 inch diameter stone. The maximum height of the rock check dam would be no greater than 3 feet and the center of the dam would be 6 inches lower than the outer edges. For added stability, the dam would be keyed into the surrounding soil approximately 6 inches deep. Filter cloth may be added under the stone to provide a stable foundation and facilitate removal of the dam. Rock check dams would be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Debris and sediment would be removed from behind the dam when it reaches a height of one half the original dam height. See Figure 8.

Sand Bag Berm – Sand bag berms would be used around Willis Creek, when the contributing drainage area is greater than 5 acres. The sand bags would be constructed from polyethylene, polyamide or cotton burlap woven fabric, have a minimum weight of four ounces per square yard, a mullen burst strength exceeding 300 PSI and ultraviolet stability exceeding 70 percent. Sand bags would be 24 to 30 inches in length, 16 to 18 inches in width and 6 to 8 inches in thickness. The sand bags would be filled with coarse grade sand, free from deterous material, and shall pass through a No 10 sieve. The minimum weight of the bag would no less than 40 lbs. See Figure 9.

The construction contractor would be able to select from these temporary measures for sediment control according to the appropriate existing conditions. The final selection of controls would have to be approved by a Corps of Engineers Contracting Officer. Many of the aforementioned stormwater controls are temporary and would be removed after final site stabilization is completed. Some of the temporary stormwater measures; however, would remain in place as permanent measures to control erosion, create additional wildlife habitat, and improve water quality.

Permanent Measures to Minimize Long-term Adverse Impacts to Water Quality

Permanent site stabilization would occur at the Willis Creek project site when construction activities permanently cease. Several of the measures previously described for temporary stabilization would applicable for permanent stabilization. Of the methods previously described for temporary stabilization, those measures that utilize natural materials such as the log and rock check dams would remain in place permanently. The log and rock check dams would provide permanent stabilization in areas where there is high erosion potential. The stabilization and reduction of soil erosion that would occur in the bank areas where these measures have been installed would eventually allow riparian vegetation to become established, create additional wildlife habitat and provide water quality benefits by filtering runoff water that flows into Willis Creek during storm events. In addition to the permanent stabilization measures previously identified, turfing work would be done from 1 April to 1 June. Live sod would be placed on all disturbed and unpaved areas. If available living sod containing native vegetation would be used. The areas to be sodded would be excavated to a sufficient depth so that the top of the sod when set in place would be about ½ inch below the surrounding soil at the outer edges of the solid sodded area. Sod would be immediately pressed firmly into contact with the sod bed by hand tamping. Screened soil of good quality would be used to fill all cracks. Sod would be watered and fertilized at an approved rate and for a duration necessary to ensure permanent survival. The native sod would serve habitat for the native wildlife species by providing food, cover, and nesting material. The sod would act as a filter to improve the water quality of Willis Creek and runoff water during storm events.

Also a non-maintenance herbaceous riparian corridor would be maintained a minimum of 5 ft from the edge of the base flow channel. Non-woody native vegetation, such as sedges, grasses, and rushes, would be allowed to establish in the zone next to the base flow channel. In addition, a forested riparian corridor containing native species, planted according to the recommendations listed in the Fish and Wildlife Coordination Act Report (Appendix F) would be established along the top of bank where it has been adversely impacted by the one-sided excavation. The forested riparian area would provide positive aesthetic benefits, sediment stabilization capability, and shading to cool the water in Willis Creek.

AQUATIC RESOURCES

Construction of a recommended plan would adversely impact approximately 13,336 linear feet of non-wetland jurisdictional waters of the United States. Adverse impacts to the aquatic resources of Willis Creek would occur through generation of poor water quality, removal of aquatic habitat, and direct mortality. Implementation of this alternative would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Eventually, the aquatic species architecture in Willis Creek would resemble that of a disturbed environment. A main characteristic of a disturbed environment is low species diversity and little aquatic habitat. Aquatic species capable of surviving in a disturbed environment would eventually dominate the Willis Creek system. The adverse impacts of implementing this alternative would be moderated through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of aquatic habitat consistent with providing the necessary level of flood protection. The avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of aquatic habitat consistent with providing the necessary level of flood protection.

Mitigation for Impacts to Aquatic Resources

It is always the mission of the Corps of Engineers to follow environmental directives to develop and implement a flood control plan that results in the least amount of adverse impacts to the natural ecosystem within a project area. The approach that the Corps takes when planning flood control projects is to first avoid as many natural resources as possible. Since many flood control projects occur in areas that also have high natural resource value, it is not always possible to totally avoid causing adverse impacts. In cases where avoidance is not possible, flood control projects are designed to minimize adverse impacts to the natural resources. And last, and least desirable, when avoiding and minimizing adverse impacts to natural resources is not possible, natural resources that would be lost as a result of a project are mitigated for.

The planning and design of the Willis Creek project implements the three facets that the Corps uses to reduce the adverse impacts to the natural environment. As indicated in the previous section, the Willis Creek project was carefully designed to avoid some very high quality natural resources. In this project at least 8 creek bends containing some superb natural resources were completely avoided by designing high flow swales that would carry floodwater across the terrestrial component of the creek bend during a storm event. The swales are designed as grass-lined earthen trapezoidal channels set at an elevation to begin receiving storm water flows equivalent to a two-year flood event. During all other times, base stream flows would be carried in the natural channel of the creek bend and the swale would be dry. Utilization of the high flow swales identified in the recommended plan for Willis Creek would preserve an estimated 2,344 linear feet of high quality riparian and aquatic habitat and non-wetland jurisdictional waters of the United States. In many areas throughout Willis Creek, it was necessary to design a flood control channel through areas that would adversely impact aquatic and terrestrial resources. Utilizing a channel design that excavated one side of the stream would minimize adverse impacts to the riparian and to some extent the aquatic community. Utilization of a one-sided channel design would allow the preservation of natural resources on one side of Willis Creek. The one-sided channel design would be implemented throughout almost the entire Willis Creek project. As indicated in the previous section, construction of a recommended plan for Willis Creek would adversely impact approximately 13,336 linear feet of non-wetland jurisdictional waters of the United States. It is estimated that this project would adversely impact at least 15 runs, riffles, and pools. In order to mitigate for the aquatic resources that would be adversely impacted, several features would be designed to be included into the flood control channel that would maintain stream stability and reestablish lost fish and benthic habitats. One of the first measures to mitigate for lost aquatic habitat would be to construct an earthen base flow channel in Willis Creek. The base flow channel would average approximately 10 feet in width and have an average depth of 2.5 feet. The dimensions are representative of the existing dimensions of Willis Creek. Willis Creek currently has a small natural base flow channel that meanders between the banks of the larger natural channel. The base flow channel that would be constructed in the proposed flood control channel would mimic the base flow streams' current sinuosity. Fifteen riffle crest structures constructed from natural stone would be placed in the base flow channel to create riffle and pool habitat. The riffle crest structures would have a V-shape crest down towards the center of the channel to direct flows away from the bank slopes and prevent erosion. The riffle crest structures would be placed along the base flow channel to create pool habitat in the same areas where pools are currently located in the natural channel. Guidance for the design of these structures can be found in "Stream Corridor Restoration, Principles, Processes, and Practices 1998". In addition to the mitigation measures previously described, native herbaceous vegetation would be allowed to colonize the invert of the flood control channel, and the top of the cleared bank would be planted with suitable hard mast producing tree species that would eventually generate a canopy contiguous with the existing trees on the opposite bank. It is estimated that the top of bank plantings would result in a restoration of 6.1 acres of riparian habitat immediately adjacent to Willis Creek. Shade from these trees would provide a thermal refuge and organic matter for the biota of Willis Creek.

In addition to implementing the above aquatic mitigation activities on site in the Willis Creek system, the Corps proposes to conduct aquatic mitigation off-sight by restoring a segment along a tributary of Willis Creek. The tributary identified for the aquatic mitigation activities is a 1,800 linear foot stretch of South Willis Creek in an area of Brownwood known as Festival Park. The aquatic mitigation site is located approximately one mile south of the project area and is a stream that had been previously channelized. The

Willis Creek in an area of Brownwood known as Festival Park. The aquatic mitigation site is located approximately one mile south of the project area and is a stream that had been previously channelized. The stream averages approximately 2 feet wide, and about 0.5 feet deep, has two small low water dams that create some pool habitat and has no meander character, or riffle and run habitat. The banks of South Willis Creek in this area contain sparse riparian vegetation that is limited to one side and the stream is littered with concrete rubble and domestic trash. Overall the aquatic habitat of the stream is very low. Restoration of South Willis Creek in Festival Park would consist of the following activities: construct a base flow channel (4 feet wide and 1 foot deep) in the system that would have a meandering pattern repeating at least four times throughout the 1,800 foot stretch; establish 5 boulder clusters (same as described for those placed in Willis Creek) throughout the reach to create small pools, riffle and runs; remove all debris from the system; and reestablish a vegetated riparian and no-mow zone 25 foot wide on both sides of the stream using the same criteria for planting diversity and success (80% survival of plants after 4 years) as indicated above for Willis Creek and the Fish and Wildlife Service Coordination Act requirements. This plan would require 2.5 acres. If in the event that at a later date the South Willis Creek area is unavailable for mitigation activities, another site indicated previously for terrestrial mitigation known as the "Bartholomew Place" would be a suitable area to do this work.

TERRESTRIAL RESOURCES

Construction of a recommended plan would adversely impact plant and animal terrestrial resources inhabiting the approximately 15.9 acres of old field habitat and 31.7 acres of forested riparian habitat along Willis Creek. Adverse impacts to terrestrial resources would occur through the removal of critical habitat essential to complete life cycle requirements and by direct mortality. The abundance and diversity of wildlife found in an area is the result of the habitat available for nesting, foraging, shelter, reproduction and rearing of young. Removal of the old field and riparian habitat would result in a reduction in the number and diversity of terrestrial wildlife species present. The reduction in the abundance and diversity of habitat resulting from implementation of this alternative would generate conditions unable to support some plant and wildlife species. With the removal of habitat, the terrestrial plant species composition along Willis Creek would change to one more characteristic of a disturbed environment, dominated by a few species that could tolerate the new environmental conditions. Of the alternatives evaluated for the Willis Creek project, this alternative avoided the greatest abundance of terrestrial habitat consistent with providing the necessary level of flood protection. Avoidance of some of the riparian habitat in the creek bends would help to preserve some wildlife species; however, isolated pockets of wildlife habitat are less effective in maintaining wildlife diversity than an intact riparian corridor.

Mitigation for Impacts to Terrestrial Resources

Development of suitable mitigation for adverse impacts to the terrestrial resources that would result from the implementation of the Willis Creek flood control project was developed in cooperation with the U.S. Fish and Wildlife Service. It was estimated by both agencies that approximately 96 acres of reforestation (80 acres) and prairie restoration (16 acres) would be required to adequately mitigate for adverse impacts to the natural resources on Willis Creek. The areas that appeared to be suitable to support mitigation activities were located on grounds around the Brownwood Municipal Airport along Pecan Bayou and a 500-acre tract locally known as the Bartholomew Place located along upper South Willis Creek south of FM45. Details of mitigation for terrestrial impacts are located in the U.S. Fish and Wildlife Coordination Act Report located in Appendix F of this document. Briefly, the terrestrial mitigation plan involves reforestation of 80 acres of grassland/oldfield habitat by planting a large quantity of hardwood trees and shrubs. A minimum of 100 hardwood trees and 50 shrubs per acre would be planted. The preferred tree species would include escarpment live oak, red oak, shin oak, post oak, Texas oak, pecan, netleaf hackberry, Texas mulberry, gum bumelia, cedar elm, and American elm. The recommended shrubs include species such as Texas persimmon, green hawthorn, down hawthorn, Reverchon hawthorn, Texas redbud, Carolina Buckthorn, rough-leaf dogwood, western soapberry, and prairie flameleaf sumac. All trees and shrubs would be adequately maintained and have a survival rate of at 80% after four growing seasons. Restoration of 16

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panicums. Some native forbs which provide high wildlife values include the partridgepeas, crotons, Illinois bundleflower, sunflowers, coneflowers, purple prairieclover, tickclover, Engelmann daisy, eryngos, lupines, wildbeans, and native wildflower mixes. In these areas mowing or other intensive maintenance activities would be restricted to the season of the year most compatible with wildlife reproduction, primarily late fall and winter.

In addition to the mitigation plan stated above for terrestrial resources the easement along the top of cleared flood control channel would be planted with approximately 6.1 acres of hard mast producing bottomland hardwood species according to the methods stated above. This would result in total terrestrial mitigation acreage of 102 acres (86 forested and 16 native prairie acres) for adverse impacts resulting from the Willis Creek project.

ENVIRONMENTAL COMPLIANCE

SECTION 404 – CLEAN WATER ACT

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document. The 404(b)(1) evaluation is presented at the end of this section.

SECTION 401 – CLEAN WATER ACT

Section 401 of the Clean Water Act (33 U.S.C. 1341) requires that any activity which could result in a discharge of a pollutant into waters of the United States obtain a certification from the State in which the discharge would originate and that the discharge comply with applicable effluent limitations and water quality standards. The recommended plan for Willis Creek would be considered a Tier II project as detailed in the "Memorandum of Agreement Between the U.S. Army Corps of Engineers and the TNRCC. A Joint Public Notice for this project between the Corps and the TNRCC to inform the public and governmental agencies would be used to initiate a 30-day comment period for the TNRCC certification. This public review period would be the same one used for NEPA compliance. A decision of denial or approval of this project for Section 401 water quality certification would be rendered at the end of the public review.

EXECUTIVE ORDER 11988 – FLOODPLAIN MANAGEMENT

Executive Order 11988, Floodplain Management, was considered during the planning of the proposed project. There are no practical alternatives to achieve the project purposes of flood damage reduction without working in the floodplain. Following project implementation, development of the Willis Creek floodplain would be managed. This would occur in accordance with Section 202(c) of the Water Resources Development Act of 1996, and the Federal requirement that within one year of project implementation, the City of Brownwood develop and submit a FPMP.

EXECUTIVE ORDER 11990 – PROTECTION OF WETLANDS

Executive Order 11990, Protection of Wetlands, was considered during planning of the proposed project. The recommended plan would not adversely impact or result in the loss of any wetland areas. The recommended plan would be in compliance with Executive Order 11990.

EXECUTIVE ORDER 12898 – ENVIRONMENTAL JUSTICE

Executive Order 12898 provides that each Federal agency identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States. Adverse impacts associated with implementation of the recommended plan would not have disproportionate impacts on minority or low-income populations.

FEDERAL THREATENED AND ENDANGERED SPECIES

The recommended plan has been review by the U.S. Fish and Wildlife Service (See Appendix F). As proposed, the recommended plan would not adversely impact and species Federally listed as threatened or endangered.

ENVIRONMENTAL MITIGATION AND INCREMENTAL ANALYSIS

Every effort was made during the planning stages of this project to avoid or minimize adverse impacts to terrestrial and aquatic natural resources. Unavoidable adverse impacts of this project would be mitigated by replacement of lost natural resources with habitat of the same or greater functional capacity and quality. In mid-September 2000, with the cooperation of the U. S. Fish and Wildlife Service, several sites were identified as potential areas for mitigation in and around the City Brownwood. A mitigation plan for adverse impacts to natural resources is jointly being developed between the Corps and the U.S. Fish and Wildlife Service.

The proposed mitigation for impacted aquatic habitat would be to construct an earthen base flow channel in disturbed areas of Willis Creek. The base flow channel would be approximately 5 feet wide x 2.5 feet deep and mimic the streams' original sinuosity. Ten low-water retention structures would be placed at base grade along the stream to create pool habitat. Aquatic habitat in creek bends where a diversion channel is planned would be avoided. Base water flow would be maintained in these bend areas by constructing small dikes of low elevation across the inlets and outlets of the diversion channels. Further definition of the mitigation plan for aquatic habitat would occur during the development of project Plans and Specifications.

SECTION 404 (b) (1) EVALUATION

I. Project Description

a. Location

Willis Creek originates about five miles southwest of Brownwood, Texas, and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. The study area is defined as the Standard Project Flood Plain along Willis Creek beginning at its confluence with Pecan Bayou and extending upstream a distance of about 22,000 feet terminating near Asbury Street. Within the study area, Willis Creek is a gently, to a moderately, meandering waterway having a top width ranging between 40- to 135-feet and depths between 4- and 11-feet. The slope is estimated to drop 2.92 feet per thousand foot of channel. Willis Creek flows in an easterly direction through the southern portion of the city of Brownwood to the confluence with Pecan Bayou. Willis Creek has 3 concrete box culvert bridges, at Austin Street, 4th Street, and 14th Street. Located further upstream is a wooden railroad bridge and an arched rock culvert bridge at Crockett Drive. Maps of the study area are shown in Figures 1, 2, 3, & 4 of this report.

b. General Description

The proposed plan for Willis Creek local flood damage reduction would be a hydraulic channel improvement approximately 15,680 feet long. The improvement would begin near Asbury Street, and extend approximately 6,400-feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel would be excavated across an open field, reconnecting to Willis Creek about 2,000-feet downstream (approximately 500-feet upstream of 4th Street). From the point, the improved channel would proceed 7,880-feet to the downstream terminus of the plan. The improved channel, including the diversion channel would have average bottom width of 40-feet, with side slopes of 1 vertical on 3.5 horizontal. The proposed plan would require modifications to two bridges. The four existing 8-foot by 6-foot culverts at 14th Street would be replaced with eight 10-foot by 10-foot culverts. Three 10-foot by 8-foot culverts would be added to the four existing 10-foot by 8-foot culverts on 4th Street. Riprap would be placed at the bridge approaches for erosion protection. Approximately 545-feet of different types of storm drain (reinforced concrete and galvanized pipe) would be extended. In addition, approximately 1,581-feet of various sanitary sewer, water, and gas utility lines would be relocated. A layout of the proposed plan is shown on Figure 8 of this report .

c. Authority and Purpose

The authority for the proposed project is Pecan Bayou watershed plan authorized by the Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968 for the purpose of flood damage reduction.

d. General Description of Dredged or Fill Material

(1) General Characteristics of Material

Most of the material that would be considered fill would result from the incidental migration of alluvial stream bank deposits during the excavation and shaping of the hydraulic channel. These alluvial deposits are low to medium plasticity clays, clayey sands and gravel. The clay is typically brown to light brown, firm to hard, silty, sandy, and gravelly. The sand and gravel are typically dark brown to light brown, poorly graded, silty, and clayey. Other filling would result from using large limestone cobbles/boulders as rip rap to armor sections of the channel around bridges and diversion channels.

(2) Quantity of Material

It is estimated that approximately 9,000 cubic yards of incidental bank material would result in fill and that approximately 2,600 cubic yards of rip rap and other fill material would be used in the channel to block diversion channels and maintain base water flow in the natural channel to preserve natural resources in that section of Willis Creek.

(3) Source of Material

The incidental alluvial material would originate on site. The rip rap would originate off site.

e. Description of the Proposed Discharge Site

(1) Location

The proposed discharge would occur along the segments of Willis Creek where excavation occurs.

(2) Size

The proposed flood damage reduction project would result in discharges along the full length of Willis Creek where excavation is occurring. It is anticipated that excavation would occur along approximately 13,336 linear feet of Willis Creek and includes a 30-foot zone of non-wetland jurisdictional waters, impacting a total area of about 9.18 acres.

(3) Type of Site

The area proposed for excavation along Willis Creek is an unconfined site that flows freely during local or regional rain events.

(4) Types of Habitat

Predominate terrestrial habitat types that were identified along Willis Creek are "Old Field" and "Riparian Forest". The old field areas are primarily devoid of large woody vegetation such as mature trees. The old field areas contain light densities of scrub shrub vegetation such as mesquite or juniper and moderate to high concentrations of cultivated grasses such as Coastal Bermuda. Riparian Forests are the highly vegetated corridors within the immediate vicinity of Willis Creek. The vegetation within the riparian corridor of Willis Creek is mostly composed of native pecan, live and red oak, hackberry, Chinaberry, greenbrier, wild grape, coralberry, American beautyberry, side oats gramma, and other plant species that provide wildlife habitat of exceptional value. Willis Creek is mostly a perennial stream, except during periods of low rainfall or extended drought. The aquatic habitat within Willis Creek is abundant and diverse. The creek contains several riffle/run/pool complexes of various depths and gravel consistency, undercut banks, rock shelf outcrops, root wads, dead fallen trees and branches.

(4) Timing and Duration of Discharge

It is anticipate that any discharges associated with the proposed project would occur only during construction activities and only during periods when the possibility for discharges are minimal. A storm water pollution prevention plan (SWPPP) would be developed for this project that would outline any and all measures necessary to temporarily and permanently stabilize the disturbed area and minimize discharge of materials into Willis Creek during construction. The SWPPP would also provide a plan to permanently stabilize the project area following implementation.

II.Factual Determinations

a. Physical Substrate Determinations

(1) Substrate Elevation and Slope

The elevation of Willis Creek is approximately 1,340 feet above mean sea level. The slope is estimated to drop 2.92 feet per thousand foot of channel.

(2) Sediment Type

The sediment in Willis Creek ranges from being clayey mud, to fine sand to unsorted gravel of various grain sizes. Throughout the creek there are limestone outcrops that occur in both the bed and stream banks.

(3) Dredged/Fill Material Movement

Movement of incidental fill material would occur during excavation and contouring activities facilitated by heavy equipment such as bulldozers and scrapers. Additional fill material movement would be minimized through implementation procedures outlined in a SWPPP that would be developed during Plans and Specs.

(4) Physical Effects on Benthos

The proposed project would result in adverse impacts to benthos. The adverse impacts would be through direct removal and mortality by excavation of stream material that contain benthic organisms or provides benthic habitat and substrate. Other impacts would result from the turbidity and suspended material generated during the excavation of the stream sediment. The suspended material would eventually settle out and bury or smother benthic organisms. Contouring of the channel side slopes could also result in burial of some benthic organisms.

(5) Other Effects

The project as proposed would result in adverse impacts to aquatic and terrestrial resources throughout the full length of the channel modification. Construction activities would result in the loss of all aquatic habitat in areas along Willis Creek that are identified for channel modification. In areas along Willis Creek that are forested, construction activities would eliminate most of the terrestrial habitat.

(6) Actions Taken to Minimize Impacts

Every effort was made to avoid or preserve valuable aquatic habitat concurrent with achieving the flood damage reduction objectives. Impacts to many creek bendways would be avoided by using "high flow" swales designed to carry flood flows directly across the land area contained inside the bend. In the creek bends, base water flow will be maintained during normal flow periods for preservation of natural resources. These high flow swales are located in areas that have minimal vegetation species diversity where the value of wild life habitat quality is low. Additional adverse impacts would be minimized through implementation of storm water pollution prevention control measures such as silt fences and temporary and permanent soil stabilization practices such as netting and planting of fast-growing native grasses.

b. Water Circulation, Fluctuation, and Salinity Determinations

(1) Water

(a) Salinity

The propose project would have no adverse impact on water salinity.

(b) Water Chemistry

The proposed project would have short-term and long-term impacts on water
chemistry. The turbidity and suspended materials generated from construction activities could alter aquatic plant communities by shading which may temporarily reduce dissolved oxygen concentration and alter pH, and alkalinity. Removal of shade trees from the riparian corridor would result in elevated water temperatures and influence the ability of the water to carry dissolved oxygen. Removal of vegetation from the riparian corridor would also reduce the amount of particulate organic material the stream receives and compromise the natural filtering capability of the riparian zone to remove nutrients from storm water run-off. Consequently, Willis Creek could become a highly eutrophic system containing high levels of phosphorus and nitrogen.

(c) Clarity

The proposed project would temporarily reduce the clarity of Willis Creek through the generation of turbidity caused by excavation of the streambed and banks.

(d) Color

The proposed project would not influence watercolor.

(e) Odor

The proposed project would not immediately influence stream odor. If in the event the stream becomes eutrophic, it is highly possible odors may originate from noxious algae blooms or fish kills.

(f) Taste

The proposed project would not immediately influence the taste of water in Willis Creek. If in the event that the stream becomes eutrophic, it is possible that populations of bacteria that emit chemicals into the water that influence taste could colonize in the system.

(g) Dissolved Gas Levels

The turbidity and suspended materials generated from construction activities could alter aquatic plant communities by shading which may temporarily reduce dissolved oxygen concentration and alter pH, and alkalinity. Removal of shade trees from the riparian corridor would result in elevated water temperatures and influence the ability of the water to carry dissolved oxygen.

(h) Nutrients

Removal of vegetation from the riparian corridor would also reduce the amount of particulate organic material the stream receives and compromise the natural filtering capability of the riparian zone to remove nutrients from storm water run-off. Consequently, Willis Creek could become a highly eutrophic system containing high levels of phosphorus and nitrogen.

(i) Eutrophication

Removal of vegetation from the riparian corridor would also reduce the amount of particulate organic material the stream receives and compromise the natural filtering capability of the riparian zone to remove nutrients from storm water run-off. Consequently, Willis Creek could become a highly eutrophic system containing high levels of phosphorus and nitrogen.

(2) Current Patterns and Circulation

(a) Current Patterns and Flow

The current patterns and flow would be permanently altered as a result of the proposed project.

(b) Velocity

Since the stream channel width would be widened, stream velocity would be significantly decreased during storm events.

(c) Stratification

Stratification would not occur in Willis Creek as a result of the proposed project.

(d) Hydrologic Regime

The hydrologic regime of Willis Creek would be altered as a result of the proposed project. Flood surface elevations would be lower and the size of the 100-year flood plain would be reduced in area.

(3) Normal Water Level Fluctuations

The proposed project would result in lower water surface elevations during flood events.

(4) Salinity Gradients

Not applicable.

(5) Actions Taken to Minimize Impacts

High-flow swales would be excavated through selected bends in Willis Creek. The swales would be of sufficient elevation to divert water during a storm event (2-year and greater). Base water flow would be maintained in the natural channel in the bends during normal stream flow periods.

c. Suspended Particulate/Turbidity Determinations

(1) Expected Changes in Suspended Particulates and Turbidity Levels in Vicinity of Disposal Site

It would be anticipated that the suspended particulate and likewise, turbidity levels would increase temporarily during construction activities on Willis Creek.

(2) Effects on Chemical and Physical Properties of the Water Column

(a) Light Penetration

Light penetration through the water column would be reduced due to the temporary increases resulting from increased turbidity levels during construction activities.

(b) Dissolved Oxygen

The turbidity and suspended materials generated from construction activities could alter aquatic plant communities by shading which may temporarily reduce dissolved oxygen concentration and alter pH, and alkalinity. Removal of shade trees from the riparian corridor would result in elevated water temperatures and influence the ability of the water to carry dissolved oxygen.

(c) Toxic Metals and Organics

The proposed project would not influence the concentrations of potentially toxic metals and organics in Willis Creek.

(d) Pathogens

The project as proposed would not influence the occurrence of pathogens in Willis Creek since no agricultural or feral vectors are in the immediate watershed.

(e) Aesthetics

The proposed flood damage reduction project on Willis Creek would adversely impact the natural aesthetics of the system due to the removal of natural features that provide habitat and life history requirements for the terrestrial and aquatic species. Removal of this habitat would also result in the loss of many resident fish and wildlife species from the Willis Creek watershed that many people would consider aesthetically beneficial.

(3) Effects on Biota

(a) Primary Production, Photosynthesis

The proposed project would temporarily adversely impact the primary production of Willis Creek. The water turbidity generated from suspended material due to construction activity in the stream would reduce light penetration into the water column restricting the amount of photosynthetic activity of benthic aquatic macrophytes and algae. A reduction in photosynthesis would result in limited dissolved oxygen output by these plants.

(b) Suspension/Filter Feeders

The proposed project would adversely impact suspension and filter feeders in Willis Creek. Excavation of the creek would cause direct mortality and remove critical habitat for these species. Construction activity would generate suspended sediment in the water column that would interfere with feeding either through food location or obstruction of feeding parts.

(c) Sight Feeders

The proposed project would adversely impact suspension and filter feeders in Willis Creek. Excavation of the creek would cause direct mortality and remove critical habitat for these species. Construction activity would generate suspended sediment in the water column that would interfere with feeding either through food location or obstruction of feeding parts.

(4) Actions taken to Minimize Impacts

Adverse impacts to photosynthesis, filter and sight feeders would be minimized during construction activities through implementation of storm water pollution prevention control measures such as silt fences, netting, sand bags or other temporary soil stabilization practices. Following implementation, channel side slopes and other structures associated with the channel would be permanently stabilized by planting of grasses and the use of rip rap where appropriate.

(d) Contaminant Determinations

There have been no contaminant determinations conducted for sediments along Willis Creek. The proposed project would not generate or redistribute any contaminants.

(e) Aquatic Ecosystem and Organism Determinations

(1) Effects on Plankton

The proposed project would adversely impact sessile and free-floating plankton through shading caused by construction related turbidity. Following project implementation, possible eutrophication and increased water temperature resulting from removal of the riparian corridor would cause changes in plankton community structure selecting for more tolerant species.

(2) Effects on Benthos

The proposed project would result in adverse impacts to benthos. The adverse impacts would be through direct mortality and removal by excavation of stream material that contain benthic organisms or provide benthic habitat and substrate. Other impacts would result from the turbidity and suspended material generated during the excavation of the stream sediment. The suspended material would eventually settle out and bury or smother benthic organisms. Contouring of the channel side slopes could also result in burial of some benthic organisms. Changes in stream conditions following project implementation would result in alterations in benthic community structure and a selection for species more tolerant of the new conditions.

(3) Effects on Nekton

The proposed project would result in adverse impacts to nekton. Construction excavation activities would physically remove or kill nekton and their food sources. Changes in stream conditions following project implementation would result in alterations in nekton community structure, selecting for species more tolerant of the new conditions.

(4) Effects on Aquatic Food Web

The proposed Willis Creek project would adversely impact the local aquatic food web. Adverse impacts to the aquatic food web would begin with the removal of most the riparian corridor. Removal of the riparian corridor would result in a reduction of terrestrial exogenous organic material that normally would go into the aquatic system. This material contributes to stream water quality to provide conditions suitable for the development of aquatic organism. Many lower invertebrates utilize this organic material as a primary food resource and to some extent for substrate and shelter. Disruption of the food resources at the base of the food chain and long-term changes in water quality would eventually alter the entire ecosystem structure to be comprised of species that would be more tolerant of new water quality and food web.

(5) Effects on Special Aquatic Sites

(a) Sanctuaries and Refuges

No sanctuaries or refuges exist on Willis Creek.

(b) Wetlands

No wetlands exist along Willis Creek.

(c) Mud Flats

No mud flats exist along Willis Creek.

(d) Vegetated Shallows

No vegetated shallow areas exist along Willis Creek.

(e) Coral Reefs

No coral reefs exist in Willis Creek.

(f) Riffle and Pool Complexes

Several riffle and pool complexes exist along Willis Creek. The riffle and pool complexes that are located in the areas identified for excavation would be adversely impacted through direct removal or structural modification. In these areas these complexes would be eliminated.

(6) Threatened and Endangered Species

No Federally or State listed threatened and endangered species have been reported in Willis Creek.

(7) Other Wildlife

Other wildlife would be adversely impacted by the proposed project. Removal of the aquatic habitat would eliminate some shelter and food resources for many forms of wildlife that live in and around Willis Creek. Elimination of the riparian corridor associated with this project would remove much of the critical habitat that many terrestrial species require for survival. The proposed project would alter the entire ecosystem of Willis Creek to an assemblage of aquatic and terrestrial plant and animal species more adapted for survival in a disturbed environment.

(8) Actions to Minimize Impacts

Efforts were made during the planning of this project to avoid any unnecessary adverse impacts to all natural resources; however, to achieve the necessary flood damage reduction objectives, complete avoidance of these resources was impossible.
A pilot channel would be used to convey base flow during non-storm periods. The pilot channel would be designed to have several riffle and pools. Impacts to many creek bends were avoided by using "high flow" swales designed to carry flood flows directly across the land area contained inside the bend. In these areas a low profile armored berm would be placed across the upstream mouth of the high flow swale. This would result in base water flow being maintained in the natural creek bend during normal flow periods for preservation resources. In the areas along Willis Creek where natural resource impacts are unavoidable, significant mitigation would occur for impacted resources. In cooperation with the United States Fish and Wildlife Service, a mitigation plan has been developed for this project and is presented in this document.

(f) Proposed Disposal Site Determinations

(1) Mixing Zone Determination

Any mixing of fill material would occur along the stream where excavation activities overlap the natural stream course.

(2) Determination of Compliance with Applicable Water Quality Standards

Activities associated with the proposed project would not immediately adversely violate any applicable State of Texas water quality standards

(3) Potential Effects on Human Use Characteristic

(a) Municipal and Private Water Supply

The project reach and the area of anticipated impacts downstream do not serve as a municipal or private water supply source.

(b) Recreational and Commercial Fisheries

The proposed project would adversely impact the recreational fisheries in Willis Creek

(c) Water Related Recreation

Other than recreational fishing, there is no water related recreation that occurs on Willis Creek.

(d) Aesthetics

Disposal of fill along Willis Creek would not adversely impact aesthetics other than what has been previously described for the construction activities associated with the project.

(e) Parks, National and Historical Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves.

None of these areas are present on Willis Creek in the area

(g) Determination of Cumulative Effects on the Aquatic Ecosystem

It is anticipated that proposed project would result in significant short-term adverse impacts to the aquatic ecosystem of Willis Creek. In the years following construction, the ecosystem along Willis Creek would adapt to the disturbed environment. Species that can tolerate the new conditions would eventually proliferate. Willis Creek represents a small tributary of the Pecan Bayou system. Adverse impacts associated with the proposed project would likely be isolated to the Willis Creek watershed and the stretch along the creek where the construction activities would occur. It is therefore anticipated that cumulative impacts to the Pecan Bayou system would be minimal.

(h) Secondary Effects on the Aquatic Ecosystem

The proposed project would have secondary impacts to the Willis Creek ecosystem. Removal of the riparian corridor and stream substrate would adversely impact most of the chemical and physical features that comprise the foundation of the terrestrial and aquatic ecosystem of Willis Creek. The proposed project would eventually alter and transform the ecosystem of Willis Creek to an assemblage of aquatic and terrestrial plant and animal species more adapted for survival in a disturbed environment. Additional adverse impacts to the Willis Creek ecosystem would be minimized through the Corps requirement that a “Floodplain Management Plan” be developed by the sponsor to control and manage activities that would further adversely impact the structure and function of the natural floodplain.

FINDING OF COMPLIANCE
FOR
WILLIS CREEK
SECTION 205
FLOOD DAMAGE REDUCTION PROJECT

1. No significant adaptations of the guidelines were made relative to this 404(b)(1) evaluation.

2. Various alternatives were screened for the Willis Creek project. The alternatives included a "no action alternative", nonstructural alternatives and structural alternatives. These alternatives were evaluated for economic and environmental acceptability and whether or not they achieved the original purposes intended for flood damage reduction. The "no action" is an alternative where no type of project is recommended.

Conditions of the human and natural environment in the study area would continue as normal without the implementation of any structural or nonstructural projects. The "no action" alternative would result in the least amount of impacts to the environment but would provide no protection for life or property in the event of a flood. The "no action" alternative was eliminated from consideration for these reasons.

Nonstructural measures for flood damage reduction utilize exclusion or removal of damageable properties from areas likely to flood. Nonstructural measures evaluated for the Willis Creek project included regulation of floodplain use, flood forecasting and warning to provide for temporary evacuation, flood-proofing, elevating structures, relocating structures and permanent evacuation. Regulation of floodplain land would provide no protection for those structures or people living there. The City of Brownwood has an effective team in place to monitor rainfall and river stages to provide ample time to provide flood forecast and warning. The City of Brownwood's flood forecast and warning system would provide minimal protection for property and people since there is no direct way of warning every resident of an impending flood event. Flood-proofing involves providing watertight coverings for doors and windows, sump pumps to drain seepage, sealing of cracks, steel bulkheads on brick walls to close off entrances. For flood water levels lower than the first floor of a home, flood-proofing could be very effective, but flood proofing has a high degree of uncertainty since the owner needs to be present and awake to implement many of the measures. Flood proofing also doesn't protect public facilities such as roads, bridges or utilities. Permanent evacuation involves the acquisition, removal of structures, and relocation of people from the floodplain. Corps experience has demonstrated that permanent evacuation is typically cost effective up to the and including the 10% Annual Chance Exceedance (10-year flood) flood plain. Results of the nonstructural alternative evaluation indicated that either of these measures would be ineffective in reducing flood damages or that residents would most probable not want to give up their property in the flood plain. The nonstructural alternatives were eliminated from consideration for these reasons.

Structural alternatives for flood damage reduction are measures to control, divert, or exclude the flow of water from flood prone areas to the extent necessary to reduce damages to property, general economic losses, and hazard to life or public health. The structural measures considered for Willis Creek included detention, levees and floodwalls, hydraulic channel improvements including bridge modifications and diversion.

While detention, levees and floodwalls are extremely effective means to prevent flood damages they can result in serious adverse impacts to environmental and cultural resources, esthetics, and often require a large amount of real estate and fiscal resources to implement. Detention, levees and floodwall alternatives for flood damage reduction along Willis Creek were eliminated from consideration for these reasons.

Hydraulic channel improvements and/or bridge modifications consist of modifying an existing channel by either increasing the cross-sectional area of the stream channel and/or an existing bridge, straightening and realigning the stream channel, and/or reducing the frictional losses of an existing channel through armoring with concrete. A preliminary evaluation of this alternative indicated that it would result in significant environmental impacts but it would provide the level of protection necessary for property and residents at a reasonable cost. The hydraulic channel alternative was further refined through a detailed evaluation of various combinations of bottom widths and alignments. This additional detailed evaluation was necessary to provide a hydraulic channel plan that provided the greatest amount of economic development consistent with protecting the natural and human environment. The practical hydraulic channel alternatives for this project had channel alignments of varying bottom widths (10, 25, 45, and 60 feet) that did not avoid significant biological resources. The hydraulic channel alternative that had a 10-foot bottom width would adversely impact 7.7 acres of old field habitat and 27.0 acres of riparian forest, the hydraulic channel alternative that had a 25-foot bottom width would adversely impact 9.1 acres of old field habitat and 33.8 acres of riparian forest, the hydraulic channel alternative that had 45-foot bottom width would adversely impact 9.9 acres of old field habitat and 37.7 acres of riparian forest, and the hydraulic channel alternative that had 60-foot bottom width would adversely impact 13.8 acres of old field habitat and 39.6 acres of riparian forest. The alternative that was selected (45-foot bottom width with diversion) was the one that avoided significant natural resources to the extent possible (adverse impacts to 15.9 acres of old field and 31.7 acres of riparian forest) and still provided the desired level of flood protection. This alternative is described in detail in Section I b. of this 404(b)(1) evaluation and will further be called the "preferred alternative".

3. The preferred alternative was evaluated for impacts (both beneficial and adverse) to the natural and human environment and compliance with local, State and Federal regulations. The results of this evaluation indicates that any discharges from construction of the preferred alternative are in compliance with applicable all State of Texas water quality standards, applicable toxic effluent standard or prohibition under Section 307 of the Clean Water.

4. The proposed project is in compliance with the Endangered Species Act of 1973 and will not harm any state or Federally listed threatened species or critical habitat

5. The project as proposed, would beneficially impact human health and welfare by providing residents and their property, the roads and bridges protection from flood events and not adversely impact any municipal or private water supplies. It is anticipated that the construction activities of the proposed Willis Creek project would adversely impact any local recreational fisheries in the creek, and disrupt populations of plankton, fish, shellfish, and resident wildlife species dependent on the Willis Creek aquatic ecosystem. In the long term, Willis Creek project would result in minimal adverse impacts to aquatic ecosystem diversity since some areas of the creek would not be disturbed. The stream productivity and stability of the aquatic ecosystem of Willis Creek would initially be adversely impacted; however, species more tolerant to the new environmental conditions of the creek would eventually establish and the stability and productivity of the system would stabilize. The economics of the area would benefit from a reduction in flood damages. With the exception of recreational fishing and wildlife viewing opportunities, recreation is unlikely to be impacted. Removal of a significant portion of the riparian corridor and replacing the natural system with a grass-lined channel would result in adverse impacts to aesthetics for those that view the natural system as aesthetically pleasing; however, most residents of Brownwood aren't likely to be concerned about the loss of this system since it is isolated and many areas around the City are rich in parks and woodlands that are readily accessible.

6. Efforts have been made throughout the planning of the proposed Willis Creek project to avoid and minimize the adverse impacts to significant environmental resources. The recommended plan for this project was selected because it produced the necessary flood damage benefits consistent with preserving the greatest amount of the Willis Creek ecosystem. Additional impacts to the system would be minimized to the extent possible by implementing appropriate and

practical best management plans (BMP) and plans outlined in an National Pollution Discharge and Elimination System (NPDES), Stormwater Pollution Prevention Plan (SWPPP) during construction to reduce erosion and stabilize banks to prevent erosion post-construction. Even though measures would be taken to avoid or minimize adverse impacts to the ecosystem of Willis Creek, destruction of fish and wildlife habitat would be unavoidable. In cooperation with the Fish and Wildlife Service a cost effective mitigation plan has been developed to compensate for the habitat quality that has been lost from the natural system.

7. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the proposed Willis Creek Flood Damage Reduction Project is specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem.

401 Certification Questionnaire

Impacts to wetlands

A. Will wetlands be disturbed, altered, or destroyed by the proposed activity?

No, it is estimated that 9.2 acres of non-jurisdictional waters of the United States would be adversely impacted

B. If wetlands will be disturbed, altered or destroyed, please complete the attached Alternatives Analysis Checklist.

Not applicable.

C. If wetlands will be impacted, is compensatory mitigation proposed?

No wetlands would be impacted by this project, however a mitigation plan developed in coordination with the U.S. Fish and Wildlife Service for project impacts is proposed. Please see mitigation plan for the proposed project in the Detailed Project Report.

Disposal of waste materials

A. Describe the methods for disposing of materials recovered from the removal or destruction of existing structures.

Please see section "Disposal Site" in the Detailed Project Report.

B. Describe the methods for disposing of sewage generated during construction. If the proposed work establishes a business or a subdivision, describe the method for disposing of sewage after completing the project.

Not applicable.

C. For marinas, describe plans for collecting and disposing of sewage from marine sanitation devices. Also, discuss provisions for the disposing of sewage generated from day-to-day activities.

Not applicable.

Water Quality Impacts

A. Describe the methods to minimize the short-term and long-term turbidity and suspended solids in the waters being dredged and/or filled. Also describe the type of sediment that will be dredged or used for fill.

Information regarding the methods proposed to minimize turbidity and description of fill is contained in the Section 404(b)(1) analysis in this section of the DPR.

B. Describe measures that will be used to stabilize disturbed soil areas, including: dredge material mounds, new levees or berms, building sites, and construction work areas. The description should include both short-term and long-term measures.

Information regarding the methods proposed to stabilize disturbed soil areas is contained in the Section 404(b)(1) analysis in this section of the DPR.

C. Discuss how hydraulically dredged material will be handled to ensure maximum settling of solids before discharging the decant water.

Not applicable.

D. Describe any methods used to test the sediments for contamination, especially when dredging in an area known or likely to be contaminated, such as downstream of municipal or industrial wastewater discharges.

Not applicable.

SUB-APPENDIX H

COST ENGINEERING

MCASES ESTIMATE

COST ESTIMATE
FEATURE DESIGN MEMO
PECAN BAYOU
BROWNWOOD, TEXAS

PROJECT COST SUMMARY

ACCOUNT	ACCOUNT	ESTIMATED COST	PERCENT CONTINGENCY	CONTINGENCY	TOTAL COST
02	RELOCATIONS	$482,320.00	25.00%	$120,580.00	$602,900.00
06	FISH AND WILDLIFE FACILITIES	$688,264.00	10.00%	$68,826.40	$757,090.40
08	ROADS, RAILROADS, AND BRIDGES	$511,397.00	25.00%	$127,849.25	$639,246.25
09	CHANELS AND CANNELS	$1,946,921.00	25.00%	$486,730.25	$2,433,651.25
	TOTAL CONSTRUCTION COST	**$3,628,902.00**		**$803,985.90**	**$4,432,887.90**
01	LANDS AND DAMAGES	$2,455,236.00	21.80%	$535,341.00	$2,990,577.00
30	PLANNING, ENGINEERING AND DESIGN	$402,171.00	10.00%	$40,217.10	$442,388.10
31	SUPERVISION AND ADMINISTRATION	$367,579.00	10.00%	$36,757.90	$404,336.90
	TOTAL PROJECT COSTS	**$6,853,888.00**		**$1,416,301.90**	**$8,270,189.90**

Pecan Bayou 09MAY01
26 March 02 Changes
Brownwood, Texas

Designed By:
Estimated By: Sears, Massey

Prepared By: Keene & Shaw

Preparation Date: 03/26/02
Effective Date of Pricing: 03/26/02

Sales Tax: 0.00%

MCACES for Windows

Release 1.2

Pecan Bayou
Brownwood, Texas

General Narrative:

The document consists of the construction cost estimates for the construction of a box culvert at 4th street over Willis Creek, a box cuvert at Custer Avenue and the grass lined channel at Willis Creek.

Quantities were provided by the appropriate elements of the design branch.

The estimste is submitted as required by EC-1110-2-538, Civil Works Project Cost Estimate - Code of Accounts, using the numbering system specified in the Chart of Accounts. Percentages allowed for contingencies represent the concensus established by various elements, i.e., Planning, Engineering & Design, Real Estate, Construction, Cost Engineering, etc.

Account Code 01 - Lands and Damages:

Data for Account Code 01.23.03.01 thru 17 was developed by the Real Estate Division. For each line item , contingencies have been allowed in different percentages. The overall average is 21.80%. These allowances were based on the degree of confidence held in each line item amount.

Account Code 02 Relocations:

The work required under this code consists of the installation of waterlines, sanitary sewer lines and electrical work. All of the work will be carried out as normal utility work and will all be associated with the grace lined channel. A contingency of 25% was assigned to these costs.

Account Code 06 - Fish and Wildlife Facilities:

Data for this account was furnished by the Fish and Wildlife group. developed by the Environmental Division. The work consists of constructing wildlife habitat and feeding facilities which includes ground preparation and planting trees and shrubs. A 10% contingency was added to the costs for this work

Account Code 08 - Roads, Railroads and Bridges

4th street over Willis Creek- The existing concrete headwalls will be removed. After all necessary excavation is accomplished a new concrete box culvert will be constructed including concrete approach slabs. Custer Avenue (14th St) Culvert - the existing culvert will be removed. After the necessary excavation is accomplished a new box cuvert with approach slabs will be constructed. The roadway will be paved. A 25% contingency was assigned to these costs.

Account Code 09: Channels and Canals

After clearing Willis Creek will be excavated as necessary for the construction of the grass lined channel. The channel will be turfed except for areas requiring riprap. The work appears to be very staightforward requiring no unusual construction methods. A 25% contingency was assigned to these costs.

Account Code 30: Planning, Engineering and Design:

Costs for this account were provided by the appropiate elements within the Fort Worth District. For each line item, 10% has been allowed for contingencies.

Account Code 31: Supervision and Administration

Costs for this account were provided by the appropriate elements within the Fort Worth District. A contingency of 10% was allowed for these costs.

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                                                  ** CONTRACTOR SETTINGS **
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                                      AMOUNT    PCT  PCT S    RISK    DIFF    SIZE  PERIOD  INVEST  ASSIST  SUBCON
------------------------------------------------------------------------------------------------------------------------------------

A Prime Markup

  Contractor's Field Overhead                 P          20.00
  Contractor's Home Office Expense            P           5.00
  Contractor's Profit                         P          10.00
  Contractor's Bond                           P           1.10

L Electrical Markup

  Contractor's Field Overhead                 P          15.00
  Contractor's Home Office Expense            P           0.00
  Contractor's Profit                         P           9.00
  Contractor's Bond                           P           0.00

B 0% Prime Markup

  Contractor's Field Overhead                 P           0.00
  Contractor's Home Office Expense            P           0.00
  Contractor's Profit                         P           0.00
  Contractor's Bond                           P           0.00
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                                                                                               QUANTY UOM     CONTRACT  CONTINGN  TOTAL COST     UNIT
-------------------------------------------------------------------------------------------------------------------------------------------

                                                    DA  Willis Creek Trap Channel-Grass                      6,853,888 1,416,302   8,270,190
                                                                                                           ----------- --------- -----------
                                                  TOTAL Pecan Bayou 09MAY01                                  6,853,888 1,416,302   8,270,190
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	QUANTY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass					
DA_01 Lands and Damages		2,455,236	535,341	2,990,577	
DA_02 Relocations		482,320	120,580	602,900	
DA_06 Fish and Wildlife Facilities		688,264	68,826	757,090	
DA_08 Roads, Railroads, and Bridges		511,397	127,849	639,246	
DA_09 Channels and Canals		1,946,921	486,730	2,433,651	
DA_30 Planning, Engineering and Design		402,171	40,217	442,388	
DA_31 Supervision and Administration		367,579	36,758	404,337	
TOTAL Willis Creek Trap Channel-Grass		6,853,888	1,416,302	8,270,190	
TOTAL Pecan Bayou 09MAY01		6,853,888	1,416,302	8,270,190	

** PROJECT OWNER SUMMARY - Sub Feat **

	QUANTY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass					
DA_01 Lands and Damages					
DA_01.23 Construction Contract Documents		2,455,236	535,341	2,990,577	
TOTAL Lands and Damages		2,455,236	535,341	2,990,577	
DA_02 Relocations					
DA_02.03 Cemetery, Utilities, & Structure		482,320	120,580	602,900	
TOTAL Relocations		482,320	120,580	602,900	
DA_06 Fish and Wildlife Facilities					
DA_06.03 Wildlife Facilities & Sanctuary		688,264	68,826	757,090	
TOTAL Fish and Wildlife Facilities		688,264	68,826	757,090	
DA_08 Roads, Railroads, and Bridges					
DA_08.01 Roads		511,397	127,849	639,246	
TOTAL Roads, Railroads, and Bridges		511,397	127,849	639,246	
DA_09 Channels and Canals					
DA_09.01 Channels		1,946,921	486,730	2,433,651	
TOTAL Channels and Canals		1,946,921	486,730	2,433,651	
DA_30 Planning, Engineering and Design					
DA_30..D Construction Contract P.E.& D		402,171	40,217	442,388	
TOTAL Planning, Engineering and Design		402,171	40,217	442,388	
DA_31 Supervision and Administration					
DA_31..A Project Office S & A		257,305	25,731	283,036	
DA_31..C District Office S & A		36,758	3,676	40,434	
DA_31.B0 Area Office S & A		73,516	7,352	80,868	

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                                                                                QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST    UNIT
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                                              TOTAL Supervision and Administration                367,579    36,758     404,337
                                                                                              ----------- --------- -----------
                                              TOTAL Willis Creek Trap Channel-Grass             6,853,888 1,416,302   8,270,190
                                                                                              ----------- --------- -----------
                                              TOTAL Pecan Bayou 09MAY01                         6,853,888 1,416,302   8,270,190
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** PROJECT OWNER SUMMARY - Element **

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                                                                   QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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DA  Willis Creek Trap Channel-Grass

DA_01  Lands and Damages

DA_01.23  Construction Contract Documents

DA_01.23.03  Real Estate Analysis Documents                                2,455,236   535,341   2,990,577
                                                                          ----------- --------- -----------
       TOTAL Construction Contract Documents                               2,455,236   535,341   2,990,577
                                                                          ----------- --------- -----------
       TOTAL Lands and Damages                                             2,455,236   535,341   2,990,577

DA_02  Relocations

DA_02.03  Cemetery, Utilities, & Structure

DA_02.03.18  Utilities                                                       482,320   120,580     602,900
                                                                          ----------- --------- -----------
       TOTAL Cemetery, Utilities, & Structure                                482,320   120,580     602,900
                                                                          ----------- --------- -----------
       TOTAL Relocations                                                     482,320   120,580     602,900

DA_06  Fish and Wildlife Facilities

DA_06.03  Wildlife Facilities &  Sanctuary

DA_06.03.73  Habitat and Feeding Facilities                                  688,264    68,826     757,090
                                                                          ----------- --------- -----------
       TOTAL Wildlife Facilities &  Sanctuary                                688,264    68,826     757,090
                                                                          ----------- --------- -----------
       TOTAL Fish and Wildlife Facilities                                    688,264    68,826     757,090

DA_08  Roads, Railroads, and Bridges

DA_08.01  Roads

DA_08.01.01  Mob, Demob and Preparatory Work                                  10,005     2,501      12,506
DA_08.01.99  Associated General Items                                        501,392   125,348     626,740
                                                                          ----------- --------- -----------
       TOTAL Roads                                                           511,397   127,849     639,246
                                                                          ----------- --------- -----------
       TOTAL Roads, Railroads, and Bridges                                   511,397   127,849     639,246

DA_09  Channels and Canals

DA_09.01  Channels
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** PROJECT OWNER SUMMARY - Element **

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                                                            QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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DA_09.01.01  Mob, Demob & Preparatory Work                                135,921    33,980     169,901
DA_09.01.99  Associated General Items                                   1,811,000   452,750   2,263,750
                                                                      ----------- --------- -----------
       TOTAL Channels                                                   1,946,921   486,730   2,433,651
                                                                      ----------- --------- -----------
       TOTAL Channels and Canals                                        1,946,921   486,730   2,433,651


DA_30  Planning, Engineering and Design

DA_30..D  Construction Contract P.E.& D

DA_30..D.DA  Plans and Specifications                                     128,852    12,885     141,737
DA_30..D.DC  Environmental Studies                                         14,820     1,482      16,302
DA_30..D.DD  HTRW Studies                                                   2,520       252       2,772
DA_30..D.DE  Cultural Resource Studies                                     69,000     6,900      75,900
DA_30..D.DF  Cost Estimates                                                16,152     1,615      17,767
DA_30..D.DX  Costruction Contract Management                               91,530     9,153     100,683
DA_30..D.DZ  Project P.E.& D.                                              79,297     7,930      87,227
                                                                      ----------- --------- -----------
       TOTAL Construction Contract P.E.& D                                402,171    40,217     442,388
                                                                      ----------- --------- -----------
       TOTAL Planning, Engineering and Design                             402,171    40,217     442,388


DA_31  Supervision and Administration

DA_31..A  Project Office S & A

DA_31..A.01  Project Office Operations                                    257,305    25,731     283,036
                                                                      ----------- --------- -----------
       TOTAL Project Office S & A                                         257,305    25,731     283,036


DA_31..C  District Office S & A

DA_31..C. 1  District Office Operations                                    36,758     3,676      40,434
                                                                      ----------- --------- -----------
       TOTAL District Office S & A                                         36,758     3,676      40,434


DA_31.B0  Area Office S & A

DA_31.B0.01  Area Office Operations                                        73,516     7,352      80,868
                                                                      ----------- --------- -----------
       TOTAL Area Office S & A                                             73,516     7,352      80,868
                                                                      ----------- --------- -----------
       TOTAL Supervision and Administration                               367,579    36,758     404,337
                                                                      ----------- --------- -----------
       TOTAL Willis Creek Trap Channel-Grass                            6,853,888 1,416,302   8,270,190
                                                                      ----------- --------- -----------
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** PROJECT OWNER SUMMARY - Element **

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                                                                          QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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                                         TOTAL Pecan Bayou 09MAY01                     6,853,888 1,416,302   8,270,190
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                                                        QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST    UNIT

DA  Willis Creek Trap Channel-Grass

DA_01  Lands and Damages

DA_01.23  Construction Contract Documents

DA_01.23.03  Real Estate Analysis Documents

DA_01.23.03_ 01  Real Estate Analysis Documents             8,000       800       8,800
DA_01.23.03_ 02  Real Estate Acquisition Document         306,000    30,600     336,600
DA_01.23.03_ 03  Real Estate Condemnation Documnt         122,000    30,500     152,500
DA_01.23.03_ 05  Real Estate Appraisal Documents           84,000    21,000     105,000
DA_01.23.03_ 06  Real Estate PL 91-646 Asst. Dcmt           6,000       600       6,600
DA_01.23.03_ 15  Real Estate Payment Documents          1,916,236   448,591   2,364,827
DA_01.23.03_ 17  Real Estate LERRD Acct. Documnts          13,000     3,250      16,250
                                                      ----------- --------- -----------
           TOTAL Real Estate Analysis Documents         2,455,236   535,341   2,990,577
                                                      ----------- --------- -----------
           TOTAL Construction Contract Documents        2,455,236   535,341   2,990,577
                                                      ----------- --------- -----------
           TOTAL Lands and Damages                      2,455,236   535,341   2,990,577


DA_02  Relocations

DA_02.03  Cemetery, Utilities, & Structure

DA_02.03.18  Utilities

DA_02.03.18_ 02  Site Work                                250,733    62,683     313,416
DA_02.03.18_ 16  Electrical                               231,587    57,897     289,484
                                                      ----------- --------- -----------
           TOTAL Utilities                                482,320   120,580     602,900
                                                      ----------- --------- -----------
           TOTAL Cemetery, Utilities, & Structure         482,320   120,580     602,900
                                                      ----------- --------- -----------
           TOTAL Relocations                              482,320   120,580     602,900


DA_06  Fish and Wildlife Facilities

DA_06.03  Wildlife Facilities &  Sanctuary

DA_06.03.73  Habitat and Feeding Facilities

DA_06.03.73_ 02  Sitework                                 688,264    68,826     757,090
                                                      ----------- --------- -----------
           TOTAL Habitat and Feeding Facilities           688,264    68,826     757,090
                                                      ----------- --------- -----------
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                                                                    QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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                                 TOTAL Wildlife Facilities &  Sanctuary               688,264    68,826     757,090
                                                                                   ----------- --------- -----------
                                 TOTAL Fish and Wildlife Facilities                   688,264    68,826     757,090


                          DA_08  Roads, Railroads, and Bridges

                          DA_08.01  Roads

                          DA_08.01.01  Mob, Demob and Preparatory Work

                          DA_08.01.01_001  Care of Water-4th St.                       10,005     2,501      12,506
                                                                                   ----------- --------- -----------
                                 TOTAL Mob, Demob and Preparatory Work                 10,005     2,501      12,506


                          DA_08.01.99  Associated General Items

                          DA_08.01.99_ 02  Site Work                                  501,392   125,348     626,740
                                                                                   ----------- --------- -----------
                                 TOTAL Associated General Items                       501,392   125,348     626,740
                                                                                   ----------- --------- -----------
                                 TOTAL Roads                                          511,397   127,849     639,246
                                                                                   ----------- --------- -----------
                                 TOTAL Roads, Railroads, and Bridges                  511,397   127,849     639,246


                          DA_09  Channels and Canals

                          DA_09.01  Channels

                          DA_09.01.01  Mob, Demob & Preparatory Work

                          DA_09.01.01_001  Care of Water                              135,921    33,980     169,901
                                                                                   ----------- --------- -----------
                                 TOTAL Mob, Demob & Preparatory Work                  135,921    33,980     169,901


                          DA_09.01.99  Associated General Items

                          DA_09.01.99_ 02  Site Work                                1,811,000   452,750   2,263,750
                                                                                   ----------- --------- -----------
                                 TOTAL Associated General Items                     1,811,000   452,750   2,263,750
                                                                                   ----------- --------- -----------
                                 TOTAL Channels                                     1,946,921   486,730   2,433,651
                                                                                   ----------- --------- -----------
                                 TOTAL Channels and Canals                          1,946,921   486,730   2,433,651


                          DA_30  Planning, Engineering and Design
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		QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
DA_30..D	Construction Contract P.E.& D						
DA_30..D.DA	Plans and Specifications						
DA_30..D.DA_ 01	Hydrology and Hydraulics			28,704	2,870	31,574	
DA_30..D.DA_ 02	Civil Engineering			30,180	3,018	33,198	
DA_30..D.DA_ 03	Utility, Road, & Bridge Relocat.			6,600	660	7,260	
DA_30..D.DA_ 04	Structural Engineering			28,050	2,805	30,855	
DA_30..D.DA_ 05	Agronomy			8,050	805	8,855	
DA_30..D.DA_ 06	Geotechnical Engineering			27,268	2,727	29,995	
	TOTAL Plans and Specifications			128,852	12,885	141,737	
DA_30..D.DC	Environmental Studies						
DA_30..D.DC_ 01	Environmental			14,820	1,482	16,302	
	TOTAL Environmental Studies			14,820	1,482	16,302	
DA_30..D.DD	HTRW Studies						
DA_30..D.DD_ 01	HTRW			2,520	252	2,772	
	TOTAL HTRW Studies			2,520	252	2,772	
DA_30..D.DE	Cultural Resource Studies						
DA_30..D.DE_ 01	Cultural Resource			69,000	6,900	75,900	
	TOTAL Cultural Resource Studies			69,000	6,900	75,900	
DA_30..D.DF	Cost Estimates						
DA_30..D.DF_ 01	Cost Engineering & Specification			16,152	1,615	17,767	
	TOTAL Cost Estimates			16,152	1,615	17,767	
DA_30..D.DX	Costruction Contract Management						
DA_30..D.DX_ 01	Preoject Management			40,000	4,000	44,000	
DA_30..D.DX_ 02	Design Branch			39,030	3,903	42,933	
DA_30..D.DX_ 03	Contracts Support Section			1,200	120	1,320	
DA_30..D.DX_ 04	Contracts Management Section			1,800	180	1,980	
DA_30..D.DX_ 05	Central Texas Area Office			2,000	200	2,200	
DA_30..D.DX_ 06	Contracting			7,500	750	8,250	

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                                                                       QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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                                    TOTAL Costruction Contract Management              91,530     9,153     100,683


                          DA_30..D.DZ  Project P.E.& D.

                          DA_30..D.DZ_ 01  Real Estate                                 50,297     5,030      55,327
                          DA_30..D.DZ_ 02  Operations and Maintenance                   4,000       400       4,400
                          DA_30..D.DZ_ 03  Plan Formulation Branch                     25,000     2,500      27,500
                                                                                  ----------- --------- -----------
                                    TOTAL Project P.E.& D.                             79,297     7,930      87,227
                                                                                  ----------- --------- -----------
                                    TOTAL Construction Contract P.E.& D               402,171    40,217     442,388
                                                                                  ----------- --------- -----------
                                    TOTAL Planning, Engineering and Design            402,171    40,217     442,388


                          DA_31  Supervision and Administration

                          DA_31..A  Project Office S & A

                          DA_31..A.01  Project Office Operations                      257,305    25,731     283,036
                                                                                  ----------- --------- -----------
                                    TOTAL Project Office S & A                        257,305    25,731     283,036


                          DA_31..C  District Office S & A

                          DA_31..C. 1  District Office Operations                      36,758     3,676      40,434
                                                                                  ----------- --------- -----------
                                    TOTAL District Office S & A                        36,758     3,676      40,434


                          DA_31.B0  Area Office S & A

                          DA_31.B0.01  Area Office Operations                          73,516     7,352      80,868
                                                                                  ----------- --------- -----------
                                    TOTAL Area Office S & A                            73,516     7,352      80,868
                                                                                  ----------- --------- -----------
                                    TOTAL Supervision and Administration              367,579    36,758     404,337
                                                                                  ----------- --------- -----------
                                    TOTAL Willis Creek Trap Channel-Grass           6,853,888 1,416,302   8,270,190
                                                                                  ----------- --------- -----------
                                    TOTAL Pecan Bayou 09MAY01                       6,853,888 1,416,302   8,270,190
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	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass						
DA_01 Lands and Damages						
DA_01.23 Construction Contract Documents						
DA_01.23.03 Real Estate Analysis Documents						
DA_01.23.03_ 01 Real Estate Analysis Documents			8,000	800	8,800	
TOTAL Real Estate Analysis Documents			8,000	800	8,800	
DA_01.23.03_ 02 Real Estate Acquisition Document						
DA_01.23.03_ 02_001 Acquistions by Local Sponsor			300,000	30,000	330,000	
DA_01.23.03_ 02_002 Review of Local Sponsor			6,000	600	6,600	
TOTAL Real Estate Acquisition Document			306,000	30,600	336,600	
DA_01.23.03_ 03 Real Estate Condemnation Documnt						
DA_01.23.03_ 03_001 Condemnations by Local Sponsor			120,000	30,000	150,000	
DA_01.23.03_ 03_002 Review of Local Sponsor			2,000	500	2,500	
TOTAL Real Estate Condemnation Documnt			122,000	30,500	152,500	
DA_01.23.03_ 05 Real Estate Appraisal Documents						
DA_01.23.03_ 05_001 Appraisals by Local Sponsor			72,000	18,000	90,000	
DA_01.23.03_ 05_002 Review of Local Sponsor			12,000	3,000	15,000	
TOTAL Real Estate Appraisal Documents			84,000	21,000	105,000	
DA_01.23.03_ 06 Real Estate PL 91-646 Asst. Dcmt						
DA_01.23.03_ 06_001 PL 91-646 Asst.by Local Sponsor			5,000	500	5,500	
DA_01.23.03_ 06_002 Review of Local Sponsor			1,000	100	1,100	
TOTAL Real Estate PL 91-646 Asst. Dcmt			6,000	600	6,600	
DA_01.23.03_ 15 Real Estate Payment Documents						
DA_01.23.03_ 15_001 Payments by Local Sponsor			1,904,236	445,591	2,349,827	
DA_01.23.03_ 15_002 PL91-646 Payments by Local Spons			10,000	2,500	12,500	

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                                                                                QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST     UNIT
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DA_01.23.03_ 15_003  Review of Local Sponsor                                  2,000       500       2,500
                                                                        ----------- --------- -----------
           TOTAL Real Estate Payment Documents                            1,916,236   448,591   2,364,827

DA_01.23.03_ 17  Real Estate LERRD Acct. Documnts                            13,000     3,250      16,250
                                                                        ----------- --------- -----------
           TOTAL Real Estate Analysis Documents                           2,455,236   535,341   2,990,577
                                                                        ----------- --------- -----------
           TOTAL Construction Contract Documents                          2,455,236   535,341   2,990,577
                                                                        ----------- --------- -----------
           TOTAL Lands and Damages                                        2,455,236   535,341   2,990,577


DA_02  Relocations

DA_02.03  Cemetery, Utilities, & Structure

DA_02.03.18  Utilities

DA_02.03.18_ 02  Site Work

DA_02.03.18_ 02_007  10" Water Line @ 4th St.           130.00 LF      11,509     2,877      14,386  110.66
DA_02.03.18_ 02_008  6" Water Line @ Bridge             145.00 LF       8,021     2,005      10,026   69.14
DA_02.03.18_ 02_009  18" S.S. Line - E. End of Bridge   280.00 LF      34,420     8,605      43,025  153.66
DA_02.03.18_ 02_010  10" S.S. Line @ Vine St.           350.00 LF      34,565     8,641      43,207  123.45
DA_02.03.18_ 02_011  16" Water Line @ Vine St.          160.00 LF      20,734     5,184      25,918  161.99
DA_02.03.18_ 02_012  10" S.S. Line @ N. of Quailrun     900.00 LF      49,462    12,366      61,828   68.70
DA_02.03.18_ 02_013  12" S.S. Line @ SW of 4th St.      160.00 LF      26,262     6,566      32,828  205.17
DA_02.03.18_ 02_014  6" Water Line                     2570.00 LF      50,755    12,689      63,444   24.69
DA_02.03.18_ 02_015  6" Water Line                      620.00 LF      15,004     3,751      18,755   30.25
                                                               ----------- --------- -----------
           TOTAL Site Work                                        250,733    62,683     313,416


DA_02.03.18_ 16  Electrical

DA_02.03.18_ 16_016  Telephone Poles                      2.00 EA       2,547       637       3,184 1591.79
DA_02.03.18_ 16_017  Power Poles w/ Hardware             22.00 EA     132,349    33,087     165,437 7519.85
DA_02.03.18_ 16_018  Underground Electrcal              575.00 LF      26,007     6,502      32,508   56.54
DA_02.03.18_ 16_019  Underground Electrcal              630.00 LF      28,461     7,115      35,577   56.47
DA_02.03.18_ 16_020  Underground Electrcal              935.00 LF      42,223    10,556      52,779   56.45
                                                               ----------- --------- -----------
           TOTAL Electrical                                       231,587    57,897     289,484
                                                               ----------- --------- -----------
           TOTAL Utilities                                        482,320   120,580     602,900
                                                               ----------- --------- -----------
           TOTAL Cemetery, Utilities, & Structure                 482,320   120,580     602,900
                                                               ----------- --------- -----------
           TOTAL Relocations                                      482,320   120,580     602,900
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                                                                                      QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST    UNIT
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                                              DA_06  Fish and Wildlife Facilities

                                              DA_06.03  Wildlife Facilities &  Sanctuary

                                              DA_06.03.73  Habitat and Feeding Facilities

                                              DA_06.03.73_ 02  Sitework

                                              DA_06.03.73_ 02_ 01  Trees                     3450.00 EA     267,820    26,782     294,602   85.39
                                              DA_06.03.73_ 02_ 02  Shrubs                    3450.00 EA     140,195    14,019     154,214   44.70
                                              DA_06.03.73_ 02_ 03  Environmental Restoration                280,249    28,025     308,274
                                                                                                        ----------- --------- -----------
                                                          TOTAL Sitework                                    688,264    68,826     757,090
                                                                                                        ----------- --------- -----------
                                                          TOTAL Habitat and Feeding Facilities              688,264    68,826     757,090
                                                                                                        ----------- --------- -----------
                                                          TOTAL Wildlife Facilities &  Sanctuary            688,264    68,826     757,090
                                                                                                        ----------- --------- -----------
                                                          TOTAL Fish and Wildlife Facilities                688,264    68,826     757,090


                                              DA_08  Roads, Railroads, and Bridges

                                              DA_08.01  Roads

                                              DA_08.01.01  Mob, Demob and Preparatory Work

                                              DA_08.01.01_001  Care of Water-4th St.                         10,005     2,501      12,506
                                                                                                        ----------- --------- -----------
                                                          TOTAL Mob, Demob and Preparatory Work              10,005     2,501      12,506


                                              DA_08.01.99  Associated General Items

                                              DA_08.01.99_ 02  Site Work

                                              DA_08.01.99_ 02_001  Demo Exist Culvert, etc-Custer     154.36 CY      26,036     6,509      32,545  210.84
                                              DA_08.01.99_ 02_002  Earthwork-Custer                   892.58 CY      13,456     3,364      16,820   18.84
                                              DA_08.01.99_ 02_003  Conc Box Culv Headwall-Custer      518.56 CY     236,772    59,193     295,965  570.74
                                              DA_08.01.99_ 02_004  Concrete Approach Slab-Custer       56.52 CY       9,256     2,314      11,570  204.71
                                              DA_08.01.99_ 02_005  Reinforcing Steel-Custer            73019 LB      61,391    15,348      76,738    1.05
                                              DA_08.01.99_ 02_006  Asphalt Paving-Custer              800.00 SY      21,183     5,296      26,478   33.10
                                              DA_08.01.99_ 02_007  Demolition of Headwalls-4th St       4.42 CY         746       186         932  210.84
                                              DA_08.01.99_ 02_008  Earthwork-4th St                   614.00 CY       9,256     2,314      11,570   18.84
                                              DA_08.01.99_ 02_009  Conc Box Culvert/Headwall-4th St   179.92 CY      99,969    24,992     124,961  694.54
                                              DA_08.01.99_ 02_010  Concrete Approach Slab-4th St       19.56 CY       3,414       854       4,268  218.19
                                              DA_08.01.99_ 02_011  Reinforcing Steel-4th St.           23685 LB      19,913     4,978      24,891    1.05
                                                                                                        ----------- --------- -----------
                                                          TOTAL Site Work                                   501,392   125,348     626,740
                                                                                                        ----------- --------- -----------
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                                                                                QUANTY UOM   CONTRACT  CONTINGN  TOTAL COST    UNIT
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                                         TOTAL Associated General Items                       501,392   125,348     626,740
                                                                                          ----------- --------- -----------
                                         TOTAL Roads                                          511,397   127,849     639,246
                                                                                          ----------- --------- -----------
                                         TOTAL Roads, Railroads, and Bridges                  511,397   127,849     639,246


                       DA_09  Channels and Canals

                       DA_09.01  Channels

                       DA_09.01.01  Mob, Demob & Preparatory Work

                       DA_09.01.01_001  Care of Water                                         135,921    33,980     169,901
                                                                                          ----------- --------- -----------
                                         TOTAL Mob, Demob & Preparatory Work                  135,921    33,980     169,901


                       DA_09.01.99  Associated General Items

                       DA_09.01.99_ 02  Site Work

                       DA_09.01.99_ 02_001  Channel Excavation             260000 CY      1,165,837   291,459   1,457,296    5.60
                       DA_09.01.99_ 02_002  Channel Clearing                48.00 AC        187,319    46,830     234,148 4878.09
                       DA_09.01.99_ 02_003  Channel Turfing                 50.00 AC        206,053    51,513     257,567 5151.33
                       DA_09.01.99_ 02_004  Pilot Channel Excavation      8500.00 CY         50,620    12,655      63,275    7.44
                       DA_09.01.99_ 02_005  Riprap @ 2 Culverts & 1 Bridge  2900.00 CY      158,887    39,722     198,609   68.49
                       DA_09.01.99_ 02_006  Bedding @ 2 Culverts & 1 Bridge  920.00 CY       42,284    10,571      52,855   57.45
                                                                                          ----------- --------- -----------
                                         TOTAL Site Work                                    1,811,000   452,750   2,263,750
                                                                                          ----------- --------- -----------
                                         TOTAL Associated General Items                     1,811,000   452,750   2,263,750
                                                                                          ----------- --------- -----------
                                         TOTAL Channels                                     1,946,921   486,730   2,433,651
                                                                                          ----------- --------- -----------
                                         TOTAL Channels and Canals                          1,946,921   486,730   2,433,651


                       DA_30  Planning, Engineering and Design

                       DA_30..D  Construction Contract P.E.& D

                       DA_30..D.DA  Plans and Specifications

                       DA_30..D.DA_ 01  Hydrology and Hydraulics                               28,704     2,870      31,574
                       DA_30..D.DA_ 02  Civil Engineering                                      30,180     3,018      33,198
                       DA_30..D.DA_ 03  Utility, Road, & Bridge Relocat.                        6,600       660       7,260
                       DA_30..D.DA_ 04  Structural Engineering                                 28,050     2,805      30,855
                       DA_30..D.DA_ 05  Agronomy                                                8,050       805       8,855
                       DA_30..D.DA_ 06  Geotechnical Engineering                               27,268     2,727      29,995
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                                                                                  QUANTY UOM    CONTRACT  CONTINGN  TOTAL COST    UNIT
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                                                  TOTAL Plans and Specifications                 128,852    12,885     141,737

                                     DA_30..D.DC  Environmental Studies

                                     DA_30..D.DC_ 01  Environmental                               14,820     1,482      16,302
                                                                                             ----------- --------- -----------
                                                  TOTAL Environmental Studies                     14,820     1,482      16,302

                                     DA_30..D.DD  HTRW Studies

                                     DA_30..D.DD_ 01  HTRW                                         2,520       252       2,772
                                                                                             ----------- --------- -----------
                                                  TOTAL HTRW Studies                               2,520       252       2,772

                                     DA_30..D.DE  Cultural Resource Studies

                                     DA_30..D.DE_ 01  Cultural Resource                           69,000     6,900      75,900
                                                                                             ----------- --------- -----------
                                                  TOTAL Cultural Resource Studies                 69,000     6,900      75,900

                                     DA_30..D.DF  Cost Estimates

                                     DA_30..D.DF_ 01  Cost Engineering & Specification            16,152     1,615      17,767
                                                                                             ----------- --------- -----------
                                                  TOTAL Cost Estimates                            16,152     1,615      17,767

                                     DA_30..D.DX  Costruction Contract Management

                                     DA_30..D.DX_ 01  Preoject Management                         40,000     4,000      44,000
                                     DA_30..D.DX_ 02  Design Branch                               39,030     3,903      42,933
                                     DA_30..D.DX_ 03  Contracts Support Section                    1,200       120       1,320
                                     DA_30..D.DX_ 04  Contracts Management Section                 1,800       180       1,980
                                     DA_30..D.DX_ 05  Central Texas Area Office                    2,000       200       2,200
                                     DA_30..D.DX_ 06  Contracting                                  7,500       750       8,250
                                                                                             ----------- --------- -----------
                                                  TOTAL Costruction Contract Management           91,530     9,153     100,683

                                     DA_30..D.DZ  Project P.E.& D.

                                     DA_30..D.DZ_ 01  Real Estate                                 50,297     5,030      55,327
                                     DA_30..D.DZ_ 02  Operations and Maintenance                   4,000       400       4,400
                                     DA_30..D.DZ_ 03  Plan Formulation Branch                     25,000     2,500      27,500
                                                                                             ----------- --------- -----------
                                                  TOTAL Project P.E.& D.                          79,297     7,930      87,227
                                                                                             ----------- --------- -----------
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	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
TOTAL Construction Contract P.E.& D			402,171	40,217	442,388	
TOTAL Planning, Engineering and Design			402,171	40,217	442,388	
DA_31 Supervision and Administration						
DA_31..A Project Office S & A						
DA_31..A.01 Project Office Operations			257,305	25,731	283,036	
TOTAL Project Office S & A			257,305	25,731	283,036	
DA_31..C District Office S & A						
DA_31..C. 1 District Office Operations			36,758	3,676	40,434	
TOTAL District Office S & A			36,758	3,676	40,434	
DA_31.B0 Area Office S & A						
DA_31.B0.01 Area Office Operations			73,516	7,352	80,868	
TOTAL Area Office S & A			73,516	7,352	80,868	
TOTAL Supervision and Administration			367,579	36,758	404,337	
TOTAL Willis Creek Trap Channel-Grass			6,853,888	1,416,302	8,270,190	
TOTAL Pecan Bayou 09MAY01			6,853,888	1,416,302	8,270,190	

** PROJECT INDIRECT SUMMARY - Contract **

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
TOTAL Pecan Bayou 09MAY01		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
Contingencies							1,416,302	
TOTAL INCL OWNER COSTS							8,270,190	

** PROJECT INDIRECT SUMMARY - Feature **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass									
DA_01 Lands and Damages			2,455,236	0	0	0	0	2,455,236	
DA_02 Relocations			344,208	68,842	20,652	43,370	5,248	482,320	
DA_06 Fish and Wildlife Facilities			491,180	98,236	29,471	61,889	7,489	688,264	
DA_08 Roads, Railroads, and Bridges			364,959	72,992	21,898	45,985	5,564	511,397	
DA_09 Channels and Canals			1,389,421	277,884	83,365	175,067	21,183	1,946,921	
DA_30 Planning, Engineering and Design			402,171	0	0	0	0	402,171	
DA_31 Supervision and Administration			367,579	0	0	0	0	367,579	
TOTAL Willis Creek Trap Channel-Grass			5,814,754	517,954	155,386	326,311	39,484	6,853,888	
TOTAL Pecan Bayou 09MAY01			5,814,754	517,954	155,386	326,311	39,484	6,853,888	
Contingencies								1,416,302	
TOTAL INCL OWNER COSTS								8,270,190	

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass								
DA_01 Lands and Damages								
DA_01.23 Construction Contract Documents		2,455,236	0	0	0	0	2,455,236	
TOTAL Lands and Damages		2,455,236	0	0	0	0	2,455,236	
DA_02 Relocations								
DA_02.03 Cemetery, Utilities, & Structure		344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Relocations		344,208	68,842	20,652	43,370	5,248	482,320	
DA_06 Fish and Wildlife Facilities								
DA_06.03 Wildlife Facilities & Sanctuary		491,180	98,236	29,471	61,889	7,489	688,264	
TOTAL Fish and Wildlife Facilities		491,180	98,236	29,471	61,889	7,489	688,264	
DA_08 Roads, Railroads, and Bridges								
DA_08.01 Roads		364,959	72,992	21,898	45,985	5,564	511,397	
TOTAL Roads, Railroads, and Bridges		364,959	72,992	21,898	45,985	5,564	511,397	
DA_09 Channels and Canals								
DA_09.01 Channels		1,389,421	277,884	83,365	175,067	21,183	1,946,921	
TOTAL Channels and Canals		1,389,421	277,884	83,365	175,067	21,183	1,946,921	
DA_30 Planning, Engineering and Design								
DA_30..D Construction Contract P.E.& D		402,171	0	0	0	0	402,171	
TOTAL Planning, Engineering and Design		402,171	0	0	0	0	402,171	
DA_31 Supervision and Administration								
DA_31..A Project Office S & A		257,305	0	0	0	0	257,305	
DA_31..C District Office S & A		36,758	0	0	0	0	36,758	
DA_31.B0 Area Office S & A		73,516	0	0	0	0	73,516	

** PROJECT INDIRECT SUMMARY - Sub Feat **

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
TOTAL Supervision and Administration		367,579	0	0	0	0	367,579	
TOTAL Willis Creek Trap Channel-Grass		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
TOTAL Pecan Bayou 09MAY01		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
Contingencies							1,416,302	
TOTAL INCL OWNER COSTS							8,270,190	

** PROJECT INDIRECT SUMMARY - Element **

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass								
DA_01 Lands and Damages								
DA_01.23 Construction Contract Documents								
DA_01.23.03 Real Estate Analysis Documents		2,455,236	0	0	0	0	2,455,236	
TOTAL Construction Contract Documents		2,455,236	0	0	0	0	2,455,236	
TOTAL Lands and Damages		2,455,236	0	0	0	0	2,455,236	
DA_02 Relocations								
DA_02.03 Cemetery, Utilities, & Structure								
DA_02.03.18 Utilities		344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Cemetery, Utilities, & Structure		344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Relocations		344,208	68,842	20,652	43,370	5,248	482,320	
DA_06 Fish and Wildlife Facilities								
DA_06.03 Wildlife Facilities & Sanctuary								
DA_06.03.73 Habitat and Feeding Facilities		491,180	98,236	29,471	61,889	7,489	688,264	
TOTAL Wildlife Facilities & Sanctuary		491,180	98,236	29,471	61,889	7,489	688,264	
TOTAL Fish and Wildlife Facilities		491,180	98,236	29,471	61,889	7,489	688,264	
DA_08 Roads, Railroads, and Bridges								
DA_08.01 Roads								
DA_08.01.01 Mob, Demob and Preparatory Work		7,140	1,428	428	900	109	10,005	
DA_08.01.99 Associated General Items		357,819	71,564	21,469	45,085	5,455	501,392	
TOTAL Roads		364,959	72,992	21,898	45,985	5,564	511,397	
TOTAL Roads, Railroads, and Bridges		364,959	72,992	21,898	45,985	5,564	511,397	
DA_09 Channels and Canals								
DA_09.01 Channels								

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                                                                        QUANTY UOM      DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST     UNIT
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                           DA_09.01.01  Mob, Demob & Preparatory Work                   97,000    19,400     5,820    12,222     1,479     135,921
                           DA_09.01.99  Associated General Items                     1,292,421   258,484    77,545   162,845    19,704   1,811,000
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Channels                                      1,389,421   277,884    83,365   175,067    21,183   1,946,921
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Channels and Canals                           1,389,421   277,884    83,365   175,067    21,183   1,946,921


                           DA_30  Planning, Engineering and Design

                           DA_30..D  Construction Contract P.E.& D

                           DA_30..D.DA  Plans and Specifications                       128,852         0         0         0         0     128,852
                           DA_30..D.DC  Environmental Studies                           14,820         0         0         0         0      14,820
                           DA_30..D.DD  HTRW Studies                                     2,520         0         0         0         0       2,520
                           DA_30..D.DE  Cultural Resource Studies                       69,000         0         0         0         0      69,000
                           DA_30..D.DF  Cost Estimates                                  16,152         0         0         0         0      16,152
                           DA_30..D.DX  Costruction Contract Management                 91,530         0         0         0         0      91,530
                           DA_30..D.DZ  Project P.E.& D.                                79,297         0         0         0         0      79,297
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Construction Contract P.E.& D                   402,171         0         0         0         0     402,171
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Planning, Engineering and Design                402,171         0         0         0         0     402,171


                           DA_31  Supervision and Administration

                           DA_31..A  Project Office S & A

                           DA_31..A.01  Project Office Operations                      257,305         0         0         0         0     257,305
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Project Office S & A                            257,305         0         0         0         0     257,305


                           DA_31..C  District Office S & A

                           DA_31..C. 1  District Office Operations                      36,758         0         0         0         0      36,758
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL District Office S & A                            36,758         0         0         0         0      36,758


                           DA_31.B0  Area Office S & A

                           DA_31.B0.01  Area Office Operations                          73,516         0         0         0         0      73,516
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Area Office S & A                                73,516         0         0         0         0      73,516
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Supervision and Administration                  367,579         0         0         0         0     367,579
                                                                                   ----------- --------- --------- --------- --------- -----------
                                 TOTAL Willis Creek Trap Channel-Grass               5,814,754   517,954   155,386   326,311    39,484   6,853,888
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** PROJECT INDIRECT SUMMARY - Element **

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
TOTAL Pecan Bayou 09MAY01		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
Contingencies							1,416,302	
TOTAL INCL OWNER COSTS							8,270,190	

** PROJECT INDIRECT SUMMARY - Level 5 **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA Willis Creek Trap Channel-Grass									
DA_01 Lands and Damages									
DA_01.23 Construction Contract Documents									
DA_01.23.03 Real Estate Analysis Documents									
DA_01.23.03_ 01 Real Estate Analysis Documents			8,000	0	0	0	0	8,000	
DA_01.23.03_ 02 Real Estate Acquisition Document			306,000	0	0	0	0	306,000	
DA_01.23.03_ 03 Real Estate Condemnation Documnt			122,000	0	0	0	0	122,000	
DA_01.23.03_ 05 Real Estate Appraisal Documents			84,000	0	0	0	0	84,000	
DA_01.23.03_ 06 Real Estate PL 91-646 Asst. Dcmt			6,000	0	0	0	0	6,000	
DA_01.23.03_ 15 Real Estate Payment Documents			1,916,236	0	0	0	0	1,916,236	
DA_01.23.03_ 17 Real Estate LERRD Acct. Documnts			13,000	0	0	0	0	13,000	
TOTAL Real Estate Analysis Documents			2,455,236	0	0	0	0	2,455,236	
TOTAL Construction Contract Documents			2,455,236	0	0	0	0	2,455,236	
TOTAL Lands and Damages			2,455,236	0	0	0	0	2,455,236	
DA_02 Relocations									
DA_02.03 Cemetery, Utilities, & Structure									
DA_02.03.18 Utilities									
DA_02.03.18_ 02 Site Work			178,936	35,787	10,736	22,546	2,728	250,733	
DA_02.03.18_ 16 Electrical			165,272	33,054	9,916	20,824	2,520	231,587	
TOTAL Utilities			344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Cemetery, Utilities, & Structure			344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Relocations			344,208	68,842	20,652	43,370	5,248	482,320	
DA_06 Fish and Wildlife Facilities									
DA_06.03 Wildlife Facilities & Sanctuary									
DA_06.03.73 Habitat and Feeding Facilities									
DA_06.03.73_ 02 Sitework			491,180	98,236	29,471	61,889	7,489	688,264	
TOTAL Habitat and Feeding Facilities			491,180	98,236	29,471	61,889	7,489	688,264	

** PROJECT INDIRECT SUMMARY - Level 5 **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
TOTAL Wildlife Facilities & Sanctuary			491,180	98,236	29,471	61,889	7,489	688,264	
TOTAL Fish and Wildlife Facilities			491,180	98,236	29,471	61,889	7,489	688,264	
DA_08 Roads, Railroads, and Bridges									
DA_08.01 Roads									
DA_08.01.01 Mob, Demob and Preparatory Work									
DA_08.01.01_001 Care of Water-4th St.			7,140	1,428	428	900	109	10,005	
TOTAL Mob, Demob and Preparatory Work			7,140	1,428	428	900	109	10,005	
DA_08.01.99 Associated General Items									
DA_08.01.99_ 02 Site Work			357,819	71,564	21,469	45,085	5,455	501,392	
TOTAL Associated General Items			357,819	71,564	21,469	45,085	5,455	501,392	
TOTAL Roads			364,959	72,992	21,898	45,985	5,564	511,397	
TOTAL Roads, Railroads, and Bridges			364,959	72,992	21,898	45,985	5,564	511,397	
DA_09 Channels and Canals									
DA_09.01 Channels									
DA_09.01.01 Mob, Demob & Preparatory Work									
DA_09.01.01_001 Care of Water			97,000	19,400	5,820	12,222	1,479	135,921	
TOTAL Mob, Demob & Preparatory Work			97,000	19,400	5,820	12,222	1,479	135,921	
DA_09.01.99 Associated General Items									
DA_09.01.99_ 02 Site Work			1,292,421	258,484	77,545	162,845	19,704	1,811,000	
TOTAL Associated General Items			1,292,421	258,484	77,545	162,845	19,704	1,811,000	
TOTAL Channels			1,389,421	277,884	83,365	175,067	21,183	1,946,921	
TOTAL Channels and Canals			1,389,421	277,884	83,365	175,067	21,183	1,946,921	
DA_30 Planning, Engineering and Design									

** PROJECT INDIRECT SUMMARY - Level 5 **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA_30..D Construction Contract P.E.& D									
DA_30..D.DA Plans and Specifications									
DA_30..D.DA_ 01 Hydrology and Hydraulics			28,704	0	0	0	0	28,704	
DA_30..D.DA_ 02 Civil Engineering			30,180	0	0	0	0	30,180	
DA_30..D.DA_ 03 Utility, Road, & Bridge Relocat.			6,600	0	0	0	0	6,600	
DA_30..D.DA_ 04 Structural Engineering			28,050	0	0	0	0	28,050	
DA_30..D.DA_ 05 Agronomy			8,050	0	0	0	0	8,050	
DA_30..D.DA_ 06 Geotechnical Engineering			27,268	0	0	0	0	27,268	
TOTAL Plans and Specifications			128,852	0	0	0	0	128,852	
DA_30..D.DC Environmental Studies									
DA_30..D.DC_ 01 Environmental			14,820	0	0	0	0	14,820	
TOTAL Environmental Studies			14,820	0	0	0	0	14,820	
DA_30..D.DD HTRW Studies									
DA_30..D.DD_ 01 HTRW			2,520	0	0	0	0	2,520	
TOTAL HTRW Studies			2,520	0	0	0	0	2,520	
DA_30..D.DE Cultural Resource Studies									
DA_30..D.DE_ 01 Cultural Resource			69,000	0	0	0	0	69,000	
TOTAL Cultural Resource Studies			69,000	0	0	0	0	69,000	
DA_30..D.DF Cost Estimates									
DA_30..D.DF_ 01 Cost Engineering & Specification			16,152	0	0	0	0	16,152	
TOTAL Cost Estimates			16,152	0	0	0	0	16,152	
DA_30..D.DX Costruction Contract Management									
DA_30..D.DX_ 01 Preoject Management			40,000	0	0	0	0	40,000	
DA_30..D.DX_ 02 Design Branch			39,030	0	0	0	0	39,030	
DA_30..D.DX_ 03 Contracts Support Section			1,200	0	0	0	0	1,200	
DA_30..D.DX_ 04 Contracts Management Section			1,800	0	0	0	0	1,800	
DA_30..D.DX_ 05 Central Texas Area Office			2,000	0	0	0	0	2,000	
DA_30..D.DX_ 06 Contracting			7,500	0	0	0	0	7,500	

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
TOTAL Costruction Contract Management		91,530	0	0	0	0	91,530	
DA_30..D.DZ Project P.E.& D.								
DA_30..D.DZ_ 01 Real Estate		50,297	0	0	0	0	50,297	
DA_30..D.DZ_ 02 Operations and Maintenance		4,000	0	0	0	0	4,000	
DA_30..D.DZ_ 03 Plan Formulation Branch		25,000	0	0	0	0	25,000	
TOTAL Project P.E.& D.		79,297	0	0	0	0	79,297	
TOTAL Construction Contract P.E.& D		402,171	0	0	0	0	402,171	
TOTAL Planning, Engineering and Design		402,171	0	0	0	0	402,171	
DA_31 Supervision and Administration								
DA_31..A Project Office S & A								
DA_31..A.01 Project Office Operations		257,305	0	0	0	0	257,305	
TOTAL Project Office S & A		257,305	0	0	0	0	257,305	
DA_31..C District Office S & A								
DA_31..C. 1 District Office Operations		36,758	0	0	0	0	36,758	
TOTAL District Office S & A		36,758	0	0	0	0	36,758	
DA_31.B0 Area Office S & A								
DA_31.B0.01 Area Office Operations		73,516	0	0	0	0	73,516	
TOTAL Area Office S & A		73,516	0	0	0	0	73,516	
TOTAL Supervision and Administration		367,579	0	0	0	0	367,579	
TOTAL Willis Creek Trap Channel-Grass		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
TOTAL Pecan Bayou 09MAY01		5,814,754	517,954	155,386	326,311	39,484	6,853,888	
Contingencies							1,416,302	
TOTAL INCL OWNER COSTS							8,270,190	

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                                                                  QUANTY UOM      DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST     UNIT
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                        DA  Willis Creek Trap Channel-Grass

                        DA_01  Lands and Damages

                        DA_01.23  Construction Contract Documents

                        DA_01.23.03  Real Estate Analysis Documents

                        DA_01.23.03_ 01  Real Estate Analysis Documents                       8,000         0         0         0         0       8,000
                                                                                      ----------- --------- --------- --------- --------- -----------
                                   TOTAL Real Estate Analysis Documents                      8,000         0         0         0         0       8,000

                        DA_01.23.03_ 02  Real Estate Acquisition Document

                        DA_01.23.03_ 02_001  Acquistions by Local Sponsor                   300,000         0         0         0         0     300,000
                        DA_01.23.03_ 02_002  Review of Local Sponsor                          6,000         0         0         0         0       6,000
                                                                                      ----------- --------- --------- --------- --------- -----------
                                   TOTAL Real Estate Acquisition Document                  306,000         0         0         0         0     306,000

                        DA_01.23.03_ 03  Real Estate Condemnation Documnt

                        DA_01.23.03_ 03_001  Condemnations by Local Sponsor                 120,000         0         0         0         0     120,000
                        DA_01.23.03_ 03_002  Review of Local Sponsor                          2,000         0         0         0         0       2,000
                                                                                      ----------- --------- --------- --------- --------- -----------
                                   TOTAL Real Estate Condemnation Documnt                  122,000         0         0         0         0     122,000

                        DA_01.23.03_ 05  Real Estate Appraisal Documents

                        DA_01.23.03_ 05_001  Appraisals by Local Sponsor                     72,000         0         0         0         0      72,000
                        DA_01.23.03_ 05_002  Review of Local Sponsor                         12,000         0         0         0         0      12,000
                                                                                      ----------- --------- --------- --------- --------- -----------
                                   TOTAL Real Estate Appraisal Documents                    84,000         0         0         0         0      84,000

                        DA_01.23.03_ 06  Real Estate PL 91-646 Asst. Dcmt

                        DA_01.23.03_ 06_001  PL 91-646 Asst.by Local Sponsor                  5,000         0         0         0         0       5,000
                        DA_01.23.03_ 06_002  Review of Local Sponsor                          1,000         0         0         0         0       1,000
                                                                                      ----------- --------- --------- --------- --------- -----------
                                   TOTAL Real Estate PL 91-646 Asst. Dcmt                    6,000         0         0         0         0       6,000

                        DA_01.23.03_ 15  Real Estate Payment Documents

                        DA_01.23.03_ 15_001  Payments by Local Sponsor                    1,904,236         0         0         0         0   1,904,236
                        DA_01.23.03_ 15_002  PL91-646 Payments by Local Spons                10,000         0         0         0         0      10,000
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** PROJECT INDIRECT SUMMARY - Level 6 **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
DA_01.23.03_ 15_003 Review of Local Sponsor			2,000	0	0	0	0	2,000	
TOTAL Real Estate Payment Documents			1,916,236	0	0	0	0	1,916,236	
DA_01.23.03_ 17 Real Estate LERRD Acct. Documnts			13,000	0	0	0	0	13,000	
TOTAL Real Estate Analysis Documents			2,455,236	0	0	0	0	2,455,236	
TOTAL Construction Contract Documents			2,455,236	0	0	0	0	2,455,236	
TOTAL Lands and Damages			2,455,236	0	0	0	0	2,455,236	
DA_02 Relocations									
DA_02.03 Cemetery, Utilities, & Structure									
DA_02.03.18 Utilities									
DA_02.03.18_ 02 Site Work									
DA_02.03.18_ 02_007 10" Water Line @ 4th St.	130.00	LF	8,213	1,643	493	1,035	125	11,509	88.53
DA_02.03.18_ 02_008 6" Water Line @ Bridge	145.00	LF	5,724	1,145	343	721	87	8,021	55.32
DA_02.03.18_ 02_009 18" S.S. Line - E. End of Bridge	280.00	LF	24,564	4,913	1,474	3,095	375	34,420	122.93
DA_02.03.18_ 02_010 10" S.S. Line @ Vine St.	350.00	LF	24,668	4,934	1,480	3,108	376	34,565	98.76
DA_02.03.18_ 02_011 16" Water Line @ Vine St.	160.00	LF	14,797	2,959	888	1,864	226	20,734	129.59
DA_02.03.18_ 02_012 10" S.S. Line @ N. of Quailrun	900.00	LF	35,299	7,060	2,118	4,448	538	49,462	54.96
DA_02.03.18_ 02_013 12" S.S. Line @ SW of 4th St.	160.00	LF	18,742	3,748	1,125	2,361	286	26,262	164.14
DA_02.03.18_ 02_014 6" Water Line	2570.00	LF	36,222	7,244	2,173	4,564	552	50,755	19.75
DA_02.03.18_ 02_015 6" Water Line	620.00	LF	10,707	2,141	642	1,349	163	15,004	24.20
TOTAL Site Work			178,936	35,787	10,736	22,546	2,728	250,733	
DA_02.03.18_ 16 Electrical									
DA_02.03.18_ 16_016 Telephone Poles	2.00	EA	1,818	364	109	229	28	2,547	1273.43
DA_02.03.18_ 16_017 Power Poles w/ Hardware	22.00	EA	94,451	18,890	5,667	11,901	1,440	132,349	6015.88
DA_02.03.18_ 16_018 Underground Electrcal	575.00	LF	18,560	3,712	1,114	2,339	283	26,007	45.23
DA_02.03.18_ 16_019 Underground Electrcal	630.00	LF	20,311	4,062	1,219	2,559	310	28,461	45.18
DA_02.03.18_ 16_020 Underground Electrcal	935.00	LF	30,133	6,027	1,808	3,797	459	42,223	45.16
TOTAL Electrical			165,272	33,054	9,916	20,824	2,520	231,587	
TOTAL Utilities			344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Cemetery, Utilities, & Structure			344,208	68,842	20,652	43,370	5,248	482,320	
TOTAL Relocations			344,208	68,842	20,652	43,370	5,248	482,320	

** PROJECT INDIRECT SUMMARY - Level 6 **

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                                                                 QUANTY UOM      DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST     UNIT
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                            DA_06  Fish and Wildlife Facilities

                            DA_06.03  Wildlife Facilities &  Sanctuary

                            DA_06.03.73  Habitat and Feeding Facilities

                            DA_06.03.73_ 02  Sitework

                            DA_06.03.73_ 02_ 01  Trees                 3450.00 EA     191,130    38,226    11,468    24,082     2,914     267,820    77.63
                            DA_06.03.73_ 02_ 02  Shrubs                3450.00 EA     100,050    20,010     6,003    12,606     1,525     140,195    40.64
                            DA_06.03.73_ 02_ 03  Environmental Restoration            200,000    40,000    12,000    25,200     3,049     280,249
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Sitework                            491,180    98,236    29,471    61,889     7,489     688,264
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Habitat and Feeding Facilities      491,180    98,236    29,471    61,889     7,489     688,264
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Wildlife Facilities &  Sanctuary    491,180    98,236    29,471    61,889     7,489     688,264
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Fish and Wildlife Facilities        491,180    98,236    29,471    61,889     7,489     688,264


                            DA_08  Roads, Railroads, and Bridges

                            DA_08.01  Roads

                            DA_08.01.01  Mob, Demob and Preparatory Work

                            DA_08.01.01_001  Care of Water-4th St.                  7,140     1,428       428       900       109      10,005
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Mob, Demob and Preparatory Work       7,140     1,428       428       900       109      10,005


                            DA_08.01.99  Associated General Items

                            DA_08.01.99_ 02  Site Work

                            DA_08.01.99_ 02_001  Demo Exist Culvert, etc-Custer    154.36 CY   18,581     3,716     1,115     2,341       283      26,036   168.67
                            DA_08.01.99_ 02_002  Earthwork-Custer                  892.58 CY    9,603     1,921       576     1,210       146      13,456    15.08
                            DA_08.01.99_ 02_003  Conc Box Culv Headwall-Custer     518.56 CY  168,973    33,795    10,138    21,291     2,576     236,772   456.60
                            DA_08.01.99_ 02_004  Concrete Approach Slab-Custer      56.52 CY    6,606     1,321       396       832       101       9,256   163.77
                            DA_08.01.99_ 02_005  Reinforcing Steel-Custer           73019 LB   43,811     8,762     2,629     5,520       668      61,391     0.84
                            DA_08.01.99_ 02_006  Asphalt Paving-Custer             800.00 SY   15,117     3,023       907     1,905       230      21,183    26.48
                            DA_08.01.99_ 02_007  Demolition of Headwalls-4th St      4.42 CY      532       106        32        67         8         746   168.67
                            DA_08.01.99_ 02_008  Earthwork-4th St                  614.00 CY    6,606     1,321       396       832       101       9,256    15.08
                            DA_08.01.99_ 02_009  Conc Box Culvert/Headwall-4th St  179.92 CY   71,343    14,269     4,281     8,989     1,088      99,969   555.63
                            DA_08.01.99_ 02_010  Concrete Approach Slab-4th St      19.56 CY    2,437       487       146       307        37       3,414   174.55
                            DA_08.01.99_ 02_011  Reinforcing Steel-4th St.          23685 LB   14,211     2,842       853     1,791       217      19,913     0.84
                                                                                  ----------- --------- --------- --------- --------- -----------
                                        TOTAL Site Work                           357,819    71,564    21,469    45,085     5,455     501,392
                                                                                  ----------- --------- --------- --------- --------- -----------
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                        ** PROJECT INDIRECT SUMMARY - Level 6 **

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                                                                 QUANTY UOM        DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST    UNIT
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                     TOTAL Associated General Items                               357,819    71,564    21,469    45,085     5,455     501,392
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Roads                                                  364,959    72,992    21,898    45,985     5,564     511,397
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Roads, Railroads, and Bridges                          364,959    72,992    21,898    45,985     5,564     511,397


        DA_09  Channels and Canals

        DA_09.01  Channels

        DA_09.01.01  Mob, Demob & Preparatory Work

        DA_09.01.01_001  Care of Water                                             97,000    19,400     5,820    12,222     1,479     135,921
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Mob, Demob & Preparatory Work                           97,000    19,400     5,820    12,222     1,479     135,921


        DA_09.01.99  Associated General Items

        DA_09.01.99_ 02  Site Work

        DA_09.01.99_ 02_001  Channel Excavation              260000 CY          832,000   166,400    49,920   104,832    12,685   1,165,837    4.48
        DA_09.01.99_ 02_002  Channel Clearing                 48.00 AC          133,680    26,736     8,021    16,844     2,038     187,319 3902.47
        DA_09.01.99_ 02_003  Channel Turfing                  50.00 AC          147,050    29,410     8,823    18,528     2,242     206,053 4121.06
        DA_09.01.99_ 02_004  Pilot Channel Excavation       8500.00 CY           36,125     7,225     2,168     4,552       551      50,620    5.96
        DA_09.01.99_ 02_005  Riprap @ 2 Culverts & 1 Bridge 2900.00 CY          113,390    22,678     6,803    14,287     1,729     158,887   54.79
        DA_09.01.99_ 02_006  Bedding @ 2 Culverts & 1 Bridge 920.00 CY           30,176     6,035     1,811     3,802       460      42,284   45.96
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Site Work                                            1,292,421   258,484    77,545   162,845    19,704   1,811,000
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Associated General Items                             1,292,421   258,484    77,545   162,845    19,704   1,811,000
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Channels                                             1,389,421   277,884    83,365   175,067    21,183   1,946,921
                                                                              ----------- --------- --------- --------- --------- -----------
                     TOTAL Channels and Canals                                  1,389,421   277,884    83,365   175,067    21,183   1,946,921


        DA_30  Planning, Engineering and Design

        DA_30..D  Construction Contract P.E.& D

        DA_30..D.DA  Plans and Specifications

        DA_30..D.DA_ 01  Hydrology and Hydraulics                                   28,704         0         0         0         0      28,704
        DA_30..D.DA_ 02  Civil Engineering                                          30,180         0         0         0         0      30,180
        DA_30..D.DA_ 03  Utility, Road, & Bridge Relocat.                            6,600         0         0         0         0       6,600
        DA_30..D.DA_ 04  Structural Engineering                                     28,050         0         0         0         0      28,050
        DA_30..D.DA_ 05  Agronomy                                                    8,050         0         0         0         0       8,050
        DA_30..D.DA_ 06  Geotechnical Engineering                                   27,268         0         0         0         0      27,268
                                                                              ----------- --------- --------- --------- --------- -----------
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** PROJECT INDIRECT SUMMARY - Level 6 **

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                                                                      QUANTY UOM     DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST     UNIT
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                            TOTAL Plans and Specifications                          128,852         0         0         0         0     128,852

                DA_30..D.DC  Environmental Studies

                DA_30..D.DC_ 01  Environmental                                        14,820         0         0         0         0      14,820
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL Environmental Studies                               14,820         0         0         0         0      14,820

                DA_30..D.DD  HTRW Studies

                DA_30..D.DD_ 01  HTRW                                                  2,520         0         0         0         0       2,520
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL HTRW Studies                                         2,520         0         0         0         0       2,520

                DA_30..D.DE  Cultural Resource Studies

                DA_30..D.DE_ 01  Cultural Resource                                    69,000         0         0         0         0      69,000
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL Cultural Resource Studies                           69,000         0         0         0         0      69,000

                DA_30..D.DF  Cost Estimates

                DA_30..D.DF_ 01  Cost Engineering & Specification                     16,152         0         0         0         0      16,152
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL Cost Estimates                                      16,152         0         0         0         0      16,152

                DA_30..D.DX  Costruction Contract Management

                DA_30..D.DX_ 01  Preoject Management                                  40,000         0         0         0         0      40,000
                DA_30..D.DX_ 02  Design Branch                                        39,030         0         0         0         0      39,030
                DA_30..D.DX_ 03  Contracts Support Section                             1,200         0         0         0         0       1,200
                DA_30..D.DX_ 04  Contracts Management Section                          1,800         0         0         0         0       1,800
                DA_30..D.DX_ 05  Central Texas Area Office                             2,000         0         0         0         0       2,000
                DA_30..D.DX_ 06  Contracting                                           7,500         0         0         0         0       7,500
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL Costruction Contract Management                     91,530         0         0         0         0      91,530

                DA_30..D.DZ  Project P.E.& D.

                DA_30..D.DZ_ 01  Real Estate                                          50,297         0         0         0         0      50,297
                DA_30..D.DZ_ 02  Operations and Maintenance                            4,000         0         0         0         0       4,000
                DA_30..D.DZ_ 03  Plan Formulation Branch                              25,000         0         0         0         0      25,000
                                                                                 ----------- --------- --------- --------- --------- -----------
                            TOTAL Project P.E.& D.                                    79,297         0         0         0         0      79,297
                                                                                 ----------- --------- --------- --------- --------- -----------
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** PROJECT INDIRECT SUMMARY - Level 6 **

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                                                  QUANTY UOM     DIRECT  FIELD OH  HOME OFC    PROFIT      BOND  TOTAL COST   UNIT
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                   TOTAL Construction Contract P.E.& D            402,171         0         0         0         0     402,171
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Planning, Engineering and Design         402,171         0         0         0         0     402,171

          DA_31  Supervision and Administration

          DA_31..A  Project Office S & A

          DA_31..A.01  Project Office Operations                  257,305         0         0         0         0     257,305
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Project Office S & A                     257,305         0         0         0         0     257,305

          DA_31..C  District Office S & A

          DA_31..C. 1  District Office Operations                  36,758         0         0         0         0      36,758
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL District Office S & A                     36,758         0         0         0         0      36,758

          DA_31.B0  Area Office S & A

          DA_31.B0.01  Area Office Operations                      73,516         0         0         0         0      73,516
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Area Office S & A                         73,516         0         0         0         0      73,516
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Supervision and Administration           367,579         0         0         0         0     367,579
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Willis Creek Trap Channel-Grass        5,814,754   517,954   155,386   326,311    39,484   6,853,888
                                                              ----------- --------- --------- --------- --------- -----------
                   TOTAL Pecan Bayou 09MAY01                    5,814,754   517,954   155,386   326,311    39,484   6,853,888

           Contingencies                                                                                            1,416,302
                                                                                                                  -----------
            TOTAL INCL OWNER COSTS                                                                                  8,270,190
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APPENDIX B

ECONOMICS

APPENDIX B

ECONOMIC ANALYSIS

PURPOSE AND METHODOLOGY

Purpose and Scope. The principal purpose of these economic analyses was to identify the extent of the flood problem and, on a comparable basis, evaluate solutions to reduce flood losses. The analyses conducted lead to the estimation of expected benefits of proposed flood reduction plans using a risk and uncertainty analysis. As part of these activities, a field survey was conducted to identify the number, type and investment value of property affected by flooding. Calculations were performed to develop estimates of the damages and benefits assignable to the various flood protection plans investigated. These analyses follow the procedures and guidelines set forth in the Water Resources Council's Principles and Guidelines (May 1983) and ER 1105-2-100 and ER 1105-2-101. Estimates of existing flood damages and benefits presented herein reflect May 2000 prices and level of development. The fiscal year 2001 Federal interest rate of 6.375 was applied to convert first costs to average annual values for the recommended. A 50-year period of analysis was assumed, extending from 2003 to 2053. Values used during plan formulation were updated by a factor of 1.08 based on the November 1997 Engineering News Record (ENR) index of 5838 and the May 2000 ENR Index of 6233.

Magnitude and Extent of Flood Problem. This report provides descriptive and analytical information on the existing flood problems along Pecan Bayou and Willis Creek. The field survey data and follow-up office analyses facilitated efforts to ascertain the severity of the flood hazard. In April 1995, an inventory was made of the flood plain lands along the subject streams to identify existing development located within the Standard Project Flood (SPF) limits. Specifically, this involved enumeration of flood plain properties, estimation of flood plain investment values, and collection of finished floor elevations. This inventory was field-checked in November 1997 to update and verify values, locations, and floor elevations. These data were used to estimate single occurrence flood losses for various events and estimate expected annual flood losses to existing properties under with and without project conditions. The damageable properties identified were classified into the seven damage categories shown in table 1.

Table 1
Major Damage Categories

Damage Category	Activity Description
Residential	Single and multifamily dwellings
Commercial & Industrial	Retail and wholesale businesses
Flood Insurance Admin.	Public costs of flood insurance program
Public	Public and quasi-public structures
Transportation	Streets, Highways, And Bridges
Communications & Utilities	Electrical, gas, telephone, sewerage, and water supply facilities and buildings
Public Health and Relief	Flood-fighting and emergency management

Floodplain Investments Identified. Determination of the value of flood plain property investments (structures and contents) for each major damage category was based on data provided by the Brown County Tax Appraisal District. These data were reviewed by the Real Estate Division personnel in Fort Worth District and considered representative of the depreciated replacement value of each structure, net of the value of associated lands. A survey was not conducted to ascertain residential content values as specified in ER 1105-2-100. In lieu of this survey, generic depth damage curves provided in Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, were used to estimate content damages. These curves reflect the results of an analysis of historical data collected from major flood events across the United States for residential structures without basements. The value of contents for commercial structures was based on direct field observation and interviews with property owners, and the relationship between structure and content values observed in prior studies.

Vehicles. Formidable practical difficulties may arise in relation to the number and value of vehicles in a flood plain and the various times that a flood might occur. Damages for automobiles were therefore estimated based on the average number of vehicles per residence characteristic of the study area, and the probability of their being present at the time of a flood. An analysis was made of registered motor vehicles per occupied housing unit for counties within Metropolitan Statistical Areas (MSA) in Texas, using data from the U.S. Census and the Texas State Department of Highways and Public Transportation. The number of registered vehicles per occupied housing unit in MSA clusters around a mean value of 2.48. Given that not all registered motor vehicles are associated with private residences, and some housing units are unoccupied, an average of 2.0 vehicles per residence is assumed for this analysis. It is anticipated that 1.5 of these would be present during non-work hours (128 hours per week) and 0.5 present during work hours (40 hours per week). The expected number of vehicles present at any given time that a flood might occur would therefore be

$$((128/168)*1.5)+((40/168)^{0.5}$$

or 1.26 expected vehicles per residence. The exact number would vary depending on the assumptions made, but for further simplicity, and conservatism, it is assumed that one vehicle per residence, which would be present at the time of a flood. This vehicle is assumed to be at the same location, stream station and ground elevation as the structure with which it is associated. Damages start when flooding reaches one foot above the ground elevation.

Calculation of the expected number of vehicles present in the flood plain at the time of a flood is irrelevant to the amount of warning time flood plain residents receive since a flood affects all vehicles present. A vehicle is usually the single most valuable item of personal property, and the most mobile. However, the majority of urban flood plains experience flooding with little or no warning time, because of either a steep flood hydrograph, a lack of a warning system, or both. Consequently, substantial vehicle damages are typically observed. In any case, the effects of increased flood warning time would take the expected number of flood plain vehicles as its baseline.

Field observations, adjusted for inflation, suggest a positive correlation between the value of a residential structure and the value of the associated vehicle. However, the relationship is not proportional, since low-valued structures can be associated with vehicles worth as much as the structure itself. Likewise, the most affluent residence can be associated with a vehicle worth a about 15 percent of the value of the structure. A plausible average value for a vehicle results by assuming the following relationship for detached single-family residences:

$$V = (0.15*S)+1000$$

where V is the vehicle value and S is the value of the residential structure. The typical residence, with a structure value in the range of $40,000 to $60,000, would have a vehicle worth $7,000 to $10,000. This is consonant with field observations and consideration of the average age of the private vehicle stock (five years), the corresponding depreciation (about fifty percent), and the average vehicle cost when new (about $15,000 to $25,000). An exception to this general formula results with mobile homes due to the lower structure value relative to the economic status of the residents, (which is the basic determinant of the value of their personal property, including vehicles). The assumed relationship for mobile homes is

$$V = (0.2*S)+1000.$$

While all of these values are assumed rather than empirical, varying them does not greatly affect the resulting assumed average vehicle value or the vehicular flood damages that result from using them. The foregoing set of assumed relationships, although hypothetical is considered realistic and a sufficient basis for planning purposes.

Flood Insurance Administrative Costs. The public incurs costs for each flood insurance policy, as reflected in the administrative costs of the National Flood Insurance Program. These costs can be avoided when a plan will remove a structure from the threat of inundation and subsequently eliminate the need for the public compensation for private damages. The average cost per policy is $146 per year as per EGM 00-4, National Flood Insurance Program Operating Costs. The city of Brown joined the program in 1981 and currently has 181 policies in effect valued at over $25.0 million.

Flood Profiles and Delineation. A full range of water surface profiles, based on existing stream conditions, were developed for this study. These profiles were used to delineate the flood plain limits and determine the relationship of damageable properties to both elevation and frequency of flood occurrence. Satisfactory development of the hydraulic model was a multi-stage iterative process in which the reasonableness of the resulting economic effects facilitated refinement of the hydraulic models.

Probability of Flood Events. USACE policy (as per ER 1105-2-101) states, "The estimate of NED benefits and costs will be reported as a single expected value and on a probabilistic basis for each planning alternative." This requires the classical nomenclature describing the relative risk of flood events to be changed to reflect the actual probability, rather than the average recurrence interval, of flood events. For example, the "100-year frequency flood", meaning that flood which stands a one percent chance of being equaled or exceeded in any given year period will hereafter be described as the "1 percent annual chance exceedence (ACE) flood." In this report, the probabilistic nomenclature is abbreviated as "1 percent ACE flood." Table 2 presents the classical terminology and the equivalent terminology used herein.

Table 2
Flood Event Category Nomenclature

Classic Terminology	*Current Terminology*
1-Year Flood	<100 Percent Annual Chance Exceedence Flood
2-Year Flood	50 Percent Annual Chance Exceedence Flood
5-Year Flood	20 Percent Annual Chance Exceedence Flood
10-Year Flood	10 Percent Annual Chance Exceedence Flood
25-Year Flood	4 Percent Annual Chance Exceedence Flood
50-Year Flood	2 Percent Annual Chance Exceedence Flood
100-Year Flood	1 Percent Annual Chance Exceedence Flood
500-Year Flood	0.2 Percent Annual Chance Exceedence Flood

Depth-Damage Relationships. The depth-damage curve file was based on data from the U.S. Flood Insurance Administration. The file has been supplemented and modified based on the findings of subsequent economic field surveys of flood plain properties in Fort Worth District, considering such factors as the design of the structure and nature of the structure contents. These curves were modified in 1996 for compatibility with the HEC-FDA program. The depth-damage relationships determine damages after a comparison between flood elevation and the finished floor elevation of each structure. A finished floor or lowest occupied floor of a building is generally higher than the local ground elevation and varies with the structure. Typically, the variance is 0.5 to 1.5 feet above the ground for most detached residences, 1.5 to 5 feet for commercial establishments, and 3 feet for mobile homes. For vehicles, the "finished floor" is defined as the bottom of the engine block and the floorboard of the passenger compartment, and is assumed one foot above the ground.

Risk and Uncertainty. Damages to the various activities, accumulated by frequency, produce a frequency-damage function. An integration process using this frequency-damage data calculates estimates of EAD. Specifically, this involves aggregating the multiplication of the mean damage between each pair of flood events by the difference in exceedance probabilities. This is then repeated for the range of flood events in each property category. The NexGen Hydrologic Engineering Center-Flood Damage Assessment Program (HEC-FDA) was developed to facilitate the plan formulation and evaluation of flood damage consistent with federal and Corps of Engineer (COE) policy regulations (ER 1105-2-100 and ER 1105-2-101). The program integrates hydrologic engineering and economic analysis through application of the Monte Carlo simulation, a technique that computes expected damage while accounting for uncertainty in the basic value. This program calculates stage-damage-uncertainty information at selected index locations and computes the EAD. Expected annual damage (EAD) is the mean damage obtained by integrating the damage exceedance probability curve for each flood event. The damage exceedance probability curve results from the discharge-exceedance probability, stage-discharge, and stage-damage functions derived at each reach index location.

Using the appropriate water surface profiles, the depth of water at each structure within the study area is calculated for the 50, 20, 10, 4, 2, 1, 0.2 and 0.125 percent ACE flood events. These depths, in combination with the damage susceptibility factors and estimated values, facilitated the calculation of expected annual damages.

Present and Most Probable Future Hydrologic Conditions. Future increases in peak discharges in the Pecan Bayou watershed were modeled in 1999. By the completion of this study, these conditions were assumed to represent existing conditions given the rapid urbanization of the watershed.

Project Benefits. Inundation reduction benefits are the difference between damages with and without the proposed project. Specifically, average annual project benefits are computed by subtracting both primary and incidental residual damages of varying alternatives form existing condition damages. Generally, the plan that exhibits the greatest net benefits (annual benefits less annual costs) is identified as the NED plan.

HISTORICAL FLOODING

Flood of 1990. The 1990 flood, a major flood for the Pecan Bayou Watershed, was produced by heavy rains in northern Texas. Flooding occurred on all major rivers in north, east, and north central Texas throughout the month of April. Extreme flooding occurred after major rainfalls from April 24 through 27 and from May 1 through May 4. Rainfall amounts of 16.5 to 18 inches were recorded in the Brownwood/DeLeon area.

Rain in the Brownwood area led to record water levels at Lake Brownwood. Water surged more than 7 feet over the emergency spillway of the lake. Many transportation routes from the city were severed and the traffic circle was submerged under several feet of water. The city remained underwater for 5 days with 7 feet of water covering most of the downtown area. Brown County suffered at least $10 million in damage from the April flood event, with over 500 residences and 70 businesses damaged. Additionally, public (city and county) facilities and agricultural damages were experienced. In addition to the economic damages from this flood, two residents of the city drowned in the flood.

Following the May flood, the President declared the State of Texas a major disaster area due to the severe thunderstorms, flooding, and tornadoes that began in April and continued through the spring. Three counties within the Pecan Bayou watershed were eligible for disaster relief: Brown, Callahan, and Mills. The public damages (PL 93-288 FEMA eligible) suffered by these three counties exceeded $640,000.

Flood of 1991. An infusion of North Pacific and the Gulf of Mexico moisture translated into some of the heaviest rains ever witnessed in wintertime in the State. An unusually intense El Nino in the tropical Pacific led to historic flooding in much of south central and southeast Texas. During the event, Brown County reported that 213 local dwellings were affected by floodwaters, with 26 structures destroyed and another 125 sustaining major damage. The city of Brownwood reported that 10 residences sustained approximate damages of $100,000 and businesses sustained over $580,000 damages in this flood event. These figures do not include lost revenue to local business, or clean-up costs.

SOCIO-ECONOMIC OVERVIEW

Population. The study area is predominately located within the city of Brownwood with a portion of Pecan Bayou in the city of Early. The city of Brownwood, incorporated in 1948 is located in west central Brown County, about 120 miles west of downtown Fort Worth. The four-county area population (Brown, Mills, Callahan, and Coleman) in 1960 totaled 49,582, of which 23,345, or about 47 percent was urban. By 1990, the population of the four-county area had grown to 60,471, of which 37,308 (or 62 percent) lived in urbanized areas. The population in Brown County in 1990 was 34,371, with 18,387 in Brownwood alone. This shows a trend of increasing total population for the area at a rate of over 350 people per year with an increasing urban population rate of over 450 people per year. As is common in most agricultural areas, changes in farm methods, increased mechanization, and improved transportation resulted in a decrease in rural population. The estimated population in 2000 exceeded 19,800 in Brownwood and 37,000 in Brown County.

Employment and Income. This metropolitan area is a major manufacturing, trade, distribution, and finance center. Other significant contributors to the local economy include agriculture, department of correction facilities, oil and gas operations, timber, and tourism. The principal manufacturing activities of the area consist of the manufacture of clothing, plumbing fixtures, brick and tile, farm machinery, leather goods, feed and cottonseed oil products, and the processing of foods, dairy products, meat and poultry. These activities employ approximately 4,000 workers. Agriculture contributes substantially to the economy of the area. The principal farm crops grown are wheat, peanuts, and hay. Livestock raised in the area include beef cattle, sheep, goats, and swine. The production of wool and mohair is of major importance along with a large production of pecans along the streams.

The county unemployment rate during 2000 was estimated at 4.0 percent, compared to the state unemployment rate of 4.3 percent. This low unemployment rate is reflected in the areas personal income. Personal income is considered the most comprehensive measure of economic activity available in this study since it maintains a close and generally constant relationship with the gross national product. The average per capita income for the county in 1998 was approximately $18,800 compared with the state average of approximately $25,400.

Study Limits. The overall study area was evaluated based on the independent hydraulic conditions of Pecan Bayou and Willis Creek. The Pecan Bayou portion includes all properties lying within the standard project flood (SPF) floodplain along Pecan Bayou and Adams Slough upstream of Lake Brownwood to the confluence with the Colorado River. Pecan Bayou is a left bank tributary of the Colorado River, entering the Colorado near Horseshoe Bend. For hydraulic purposes, the limits of the Pecan Bayou Study area extend from near the confluence with the Colorado River (Station 6+86) to the tailwater of Lake Brownwood (Station 2988+48).

The Willis creek portion includes all properties lying within the standard project flood (SPF) floodplain along Willis Creek, a right bank tributary of Pecan Bayou Pecan Bayou that enters downstream of the Atchison, Topeka and Santa Fe Railroad. The limits of Willis Creek extend from station 6+65 to an area upstream of FM 45 located at station 143+15. The limits of the Willis Creek model are from 9000 feet below Oakpark Drive (station -90+00) to 1700 feet above Highway 377 (station 249+09). The area was not subdivided into reaches.

Economic Analysis of Pecan Bayou Watershed

Pecan Bayou Description. The study area is defined as the Standard Project Flood Plain along Pecan Bayou from a point approximately 2,000-feet upstream of U.S. Highway 377, extending downstream to FM 2129, about 5,000-feet downstream of the confluence with Willis Creek, a distance of approximately 22,000- feet. Within the study area, Pecan Bayou is a gently, to a moderately, meandering waterway having a top width ranging between 135- to 215-feet and depths between 22- and 32-feet. The slope is estimated to drop 0.53 feet per thousand foot of channel. About 500-feet upstream of U.S. Highway 377, a concrete structure is located across the bayou, and produces a permanent pool of water for the adjacent Riverside Park. Pecan Bayou flows in a south-southeasterly direction through the eastern portion of the city of Brownwood in the study area, and is bounded by FM 2525 (Williams Ranch Road) to the north and Atchison Topeka and Santa Fe Railroad to the south.

Flood Plain Investment. Table 3 displays the number and estimated value of properties located within the area surveyed. Field investigations identified 749 damageable structures within the SPF limits of Pecan Bayou and Adams Slough. As shown, the total estimated value of the SPF flood plain investment is $78.5 million, based on May 2000 prices and level of development. Commercial property (structure and contents) accounts for about 70 percent of the total flood plain investment with an average value of $130,000. Residential values constitute 12 percent of the total flood plain investment with an average value of $12,900 for single-family residences. Residential content values were based on assessments from a similar project site in Graham, Texas. The remaining investments stem from privately owned vehicles and railroad tracks.

Table 3
Estimated Investment Value of Pecan Bayou and Adams Slough Flood Plain Properties

($1000, May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	274	$ 32,800	$ 22,600	$ 55,400
Single Family	450	$ 5,800	$ 2,900	$ 8,700
Multi-Family	13	$ 300	$100	$ 400
Subtotal	749	$ 41,900	$ 22,000	$ 64,500
Vehicles				$ 1,000
Rail				$ 13,000
Total Investment	**749**	**$ 38,900**	**$ 25,600**	**$ 78,500**

Single-Occurrence Flood Losses Table 4 displays a summary of the number of affected structures, structure (and content) damages, vehicle and rail damages, and total damages by flood occurrence within the Pecan Bayou study area not accounting for risk and uncertainty. It is estimated that an SPF event could cause structure and content damages of about $37.0 million. This would represent a loss of about 47 percent of total SPF floodplain investment. The one-percent ACE flood event could produce losses of nearly $15.0 million, and the 10-percent event over 0.8 million. A predominance of commercial structures would be subject to flooding in the most frequent flood zones. Overall, about 50 percent of the damageable property identified would be subject to the one-percent ACE flood.

Table 4
Cumulative Estimated Single Occurrence Flood Losses Structures, Contents under Existing Conditions

(000, based on May 2000 price and development level)

Flood Event	Commercial		Single-Family*		Multi-Family		POV	Rail	Total
	Damage	No.	Damage	No.	Damage	No.	Damage	Damage	Damage
20%									
10%	$ 710	38	$ 60	17	$ 20	1	$ 20	$ 30	$ 840
4%	$ 4,710	93	$ 550	61	$110	9	$ 140	$ 180	$ 5,690
2%	$ 7,850	129	$1,130	126	$180	9	$ 250	$ 480	$ 9,890
1%	$11,200	141	$1,960	222	$240	9	$ 410	$1,020	$14,830
0.4%	$19,020	204	$4,400	366	$350	13	$ 810	$2,950	$27,530
0.2%	$24,070	274	$6,540	450	$390	13	$1,130	$4,770	$36,900

*Includes mobile homes.

Existing Condition Expected Annual Damages. Estimates of expected annual damages (EAD) using the risk and uncertainty are presented in table 5. The expected annual flood losses in the study area totaled $733,000 based on May 2000 prices, of which 75 percent is associated with commercial development and 15 percent with residential development (including POV's).

Table 5
Expected Average Annual Damages Under Without Project Conditions

(000, based on May 2000 price and development level)

Type	Damage		% of Total
Commercial	$	553	75%
Residential	$	96	13%
Multi-Family	$	12	2%
Mobile	$	1	0%
POV	$	19	3%
Rail	$	52	7%
Total	**$**	**733**	**100%**

Investigated Alternatives.

Nonstructural alternatives were not evaluated since a buyout was not desired by the city of Brownwood given the significant number of commercial properties located in frequently flooded areas. Structural alternatives to reduce flooding in the Pecan Bayou watershed were developed to account for the split flow between Pecan Bayou and the Adam's Slough Bypass. Several options were evaluated to improve Pecan Bayou and leave Adam's Slough unchanged. Option PB50 would widen the low water dam by 50-feet. This option had little effect in producing benefits of only $300. The project first cost to widen the dam was estimated at about $3.7 million with annual costs of $267, 000 and a benefit to cost ratio well below unity. Therefore, additional options incorporated this 50-foot widening of the low water dam to channel improvements with bottom widths of 50-, 70- and 100-feet. Annual benefits for these additional options were $101,000, $115,000, and $131,000 respectively. Since these options would be significantly more expensive than the option to simply widen the dam, total project costs were not estimated.

Alternatives that would improve Adam's Slough and leave Pecan Bayou unchanged consist of a 10,513-foot channel with bottom widths of 10-, 50-, and 100 feet (designated as AS10, AS50, and AS100). As shown in table 6, neither of these projects demonstrates economic feasibility. Therefore, analysis of the Pecan Bayou Watershed was terminated.

Table 6
Economic Analysis of Structural Plans

($1000, May 2000 prices and levels of development

Alternative	Residual Damages	Flood Reduction	Insurance Subsidy	Annual Benefits	Annual Costs	Net Benefits	B/C Ratio
No Action	$ 735						
PB50	$ 729	$ 5.9		$ 5.9	$ 277.0	$ (271.1)	0.02
AS10	$ 647	$ 88.1		$ 88.1	$ 245.0	$ (157.4)	0.36
AS50	$ 631	$ 104.1	$ 0.1	$ 104.3	$ 436.0	$ (331.9)	0.24
AS100	$ 615	$ 120.1	$ 0.4	$ 120.6	$ 626.0	$ (505.5)	0.19

Economic Analysis of the Willis Creek Watershed

Willis Creek Description. Willis Creek originates about five miles southwest of Brownwood and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. The SPF delineation defines the study area along Willis Creek beginning at its confluence with Pecan Bayou and terminating near Asbury Street.

Flood Plain Investment. Table 7 displays the number and estimated value of properties located within the area surveyed. Field investigations identified 322 damageable structures within the SPF limits of Willis Creek. As shown, the total estimated value of the SPF flood plain investment is about $37.3 million, based on May 2000 prices and level of development. Residential values constitute 92 percent of the total flood plain investment with an average value of $65,500 for single-family residences. The remaining investment of $2.5 million stems from privately owned vehicles.

Table 7
Estimated Investment Value of Willis Creek
Flood Plain Properties
($000, May 2000 prices and levels of development)

Type	Number	Structure	Content	Total
Commercial	5	$ 400	$ 300	$ 700
Single Family	296	$ 19,400	$9,700	$ 29,100
Multi-Family	21	$ 3,300	$1,700	$ 5,000
Subtotal	322	$ 23,100	$ 272	$ 34,800
Vehicles		$ 2,500		$ 2,500
Total Investment		$ 25,600	$ 272	$ 37,300

Single-Occurrence Flood Losses. A summary of the cumulative number and type and the associated damages of affected structures and vehicles, by flood occurrence not accounting for risk and uncertainty in presented in Table 8. It is estimated that an SPF event could cause structure and content damages of about $11.8 million. This would represent a loss of about 45 percent of the SPF floodplain investment. The one-percent ACE could produce flood approaches the damage level of a SPF event with losses of $9.2 million, while the 10 percent event produces about $3.6 million in damages. A predominance of residential structures would be subject to flooding in all the flood zones. Overall, about 85 percent of the damageable property identified would be subject to the one-percent ACE flood event. Property's within the 10 percent ACE flood event constitute about 45 percent of the total number of structures potentially damaged along Willis Creek.

Table 8
Cumulative Estimated Single Occurrence Flood Losses Structures, Contents under Existing Conditions Without Risk and Uncertainty

(000, based on May 2000 price and development level)

Flood	Commercial		Single-Family*		Multi-Family		All Structures		POV	Total
Event	Damage	No.	Damage	No.	Damage	No.	Damages	No.	Damage	Damage
20%			$ 606	52	$ 266	4	$ 872	56	$ 23	$895
10%			$2,889	138	$ 521	6	$3,410	144	$ 155	$3,565
4%			$5,006	205	$ 746	9	$5,751	214	$ 438	$6,189
2%		1	$6,385	242	$ 924	13	$7,309	255	$ 696	$8,006
1%	$ .5	3	$7,280	260	$1,065	13	$8,347	276	$ 882	$9,229
0.2%	$ 30.4	5	$8,350	296	$1,225	21	$9,591	322	$1,305	$11,939

Existing Condition Expected Annual Damages. Table 9 summarize estimates of expected annual damages (EAD) accounting for risk and uncertainty. Expected annual flood losses to structures in the study area total $956,600 based on May 2000 prices. Flooding in residential areas constitutes 95 percent of the expected annual damage.

Table 9
Existing Expected Average Annual Damages

(Based on May 2000 price levels)

Property Type	Annual Damages
Single-Family	$ 755.2
Multi-Family	$ 131.2
Commercial	$ 1.4
Vehicles	$ 68.9
Total	$ 956.6

INVESTIGATED PLANS

No Action Plan. Not responding to the identified flooding problems in the study area is an option that warrants consideration. In action constitutes a willingness too accept the financial burden of nearly 1.0 million in annual flood damages. This alternative would be unacceptable to the city of Brownwood if a feasible alternative were identified.

Nonstructural Measures. Nonstructural measures were evaluated in accordance with "Implementation Guidance for Section 219 of the Water Resources Development Act of 1999, Nonstructural Flood Control Projects." The evaluated plans would permanently evacuate structures located within the 50-, 10-, or 1-percent ACE flood zones. An individual analysis of the structures was performed to determine the feasibility of a buy-out or permanent evacuation plan for each zone. It is recognized the actual costs would require a detailed appraisal and cost estimate in the event that this plan is selected by the sponsor. For the purposes of this analysis, procedures and costs associated with the Johnson Creek nonstructural plan in Arlington, Texas was used to develop economic and financial costs. Therefore, a demolition cost of $19,500 was used for each residential structure and $168,000 for the apartment complex. Benefits and costs derived from the nonstructural evaluation of this plan are presented in table 10.

Under the implementation guidance provided, flood damage reduction benefits are equal to the total flood damages reduced. These include damage to the structure, vehicles and incidental damages (emergency, infrastructure, clean-up). The Brown County Appraisal District certified property values was used as a proxy for the market values. These values are assumed to be within 10 percent of market values. Based on a preliminary evaluation of comparable structure values in the immediate vicinity surrounding the study area, no discernable difference in residential values was found when comparing floodplain versus non-floodplain properties. Typically it is assumed that structures carrying inordinately low values would require extensive repairs to bring them up to decent, safe, and sanitary (DSS) standards, as cited in the Section 219 implementation guidance. However, this phenomenon was not evident in this study area. Therefore, no adjustment for DSS was made to the flood-free market value. The total economic cost of evacuation includes the purchase price of the damageable structures and associated lands, vacant lands between properties (community cohesion), structure demolition costs, and the cost to remove the existing infrastructure.

In addition to the economic costs, the nonstructural project also incurs financial costs that are not used to compute the benefit-to-cost ratio. These costs primarily consist of moving expenses and relocation assistance in an amount up to $22,500 would be available to each residential property owner in accordance with PL91-646 to aid them in relocating to property outside the flood plain. Renters can be allotted moving expenses up to $5,200. Relocation and reestablishment costs for the apartment complex was estimated at $50,000. Upon implementation, detailed assessments would be required to calculate such costs.

The 50 percent ACE alternative would permanently evacuate 54 structures. This zone contains both single and multi-family properties. Project first costs were estimated at $6.5 million. The computed annual benefits and costs are $389,000 and $384,000 respectively. The resultant BCR is 1.0 to 1.0. To eliminate damages within the 10 percent ACE flood event, 143 structures would require purchase at a cost of over $10.4 million. The computed annual benefits and benefits were $776.7 and $1.1 million respectively. Purchase of the one-percent flood plain would remove 273 structures at a cost of $30.9 million. The computed average annual costs and benefits were $1.0 million and $2.2 million respectively. As shown, the resultant benefit-to-cost ratio for the 10- and one-percent zones was below unity. The addition of recreational facilities was not considered since adequate faculties are available in the city. Given the large number of structures, details for individual structures are not presented.

Table 10
Benefits of Nonstructural Alternatives
($1000, May 2000 prices and levels of development)

Flood Event	No.	Flood Free Value	Demolition Costs	Economic Costs	Annual Benefits	Annual Costs	Net Benefits	BCR	Financial Costs
0-20%	54	$ 4,387.6	$1,062.3	$ 5,450.0	$ 389.0	$ 384.0	$ 5	1.0	$1,527.0
0-10%	144	$ 9,186.7	$1,218.3	$ 10,405.0	$ 776.7	$ 1,072.0	($672)	0.4	$3,198.0
0-1%	274	$ 25,192.3	$8,661.4	$ 30,854.0	$1,033.0	$ 2,234.0	($1,201)	0.5	$5,661.4

Structural Measures. The proposed structural modification evaluated in detail was a grass-lined, trapezoidal channel that would begin about 1,200 downstream of 14th Street and extend downstream a distance of 2,000 feet, reentering Willis Creek about 500-feet upstream of 4th Street. The channel was evaluated for bottom-widths of 10-, 25-, 45-, and 60-feet. These plans would produce a damage reduction ranging from 35 percent to 70 percent. Planning level cost estimates were used to determine the feasibility of these options. A summary of the residual damages and resulting benefits is presented in Table 11.

Table 11
Economic Benefits of Structural Plans
for Willis Creek

($1000, May 2000 prices and levels of development)

Alternatives	Residual Damages	Flood Benefits	Insurance Benefits	Total Benefits	% Damage Reduction
No Action	$ 956.6				
10-foot	$ 509.3	$ 447.3	$ 5.7	$ 453.0	47%
25-foot	$ 253.6	$ 703.0	$ 13.3	$ 716.3	75%
45-foot	$ 112.4	$ 844.2	$ 35.6	$ 879.9	92%
60-foot	$ 63.1	$ 893.5	$ 37.7	$ 931.1	97%

Table 12 shows the results of the economic analysis for each channel plan. As shown, the 45-foot bottom-width channel produces the greatest net benefits with total and annual project costs of $5.9 million and $448,300, respectively. This plan would reduce expected annual damages of by 66 percent; eliminate all damages caused by the 10 percent ACE event and 90 percent of the damages caused by the 1-percent event. The resultant plan has a benefit-cost ratio of 2.0 to 1.0 and net benefits (annual benefits in excess of annual costs) of about $431,600. The optimization curve presented in figure 1 graphically depicts the net benefits associated with the channel and confirms the 45-foot channel as the NED plan. The 45-foot NED plan was further refined to include a diversion segment with less environmental impact. While residual annual damages would remain unchanged, mitigation costs would be reduced and an equivalent and proportional cost savings is assumed for the 10-, 45-, and 60-foot plans. Table 13 shows the number of structures in each flood zone following plan implementation and table 14 shows the total number of structures removed from each flood zone following project implementation.

Table 12
Economic Analysis of Structural Plans
For Willis Creek

($1000, May 2000 prices and levels of development)

	10-foot	25-foot	45-foot	60-foot	45-foot Diversion
Estimated First Cost	$3,765,600	$4,321,300	$5,978,700	$6,735,300	$5,942,400
Construction Period (Months)	12	15	18	21	18
Investment Cost	$3,888,997	$4,499,271	$6,275,785	$7,127,892	$6,237,681
Operation/Maintenance ($/Year)	$10,000	$12,500	$15,000	$17,500	$17,500
Total Annual Charges	**$278,510**	**$323,146**	**$448,303**	**$509,635**	**$445,672**
Total Annual Benefits	**$452,954**	**$716,276**	**$879,854**	**$931,200**	**$879,854**
Net Benefits	$174,444	$393,130	$431,551	$421,565	$434,182
Benefit-to-Cost Ratio	**1.6**	**2.2**	**2.0**	**1.8**	**2.0**

Figure 1

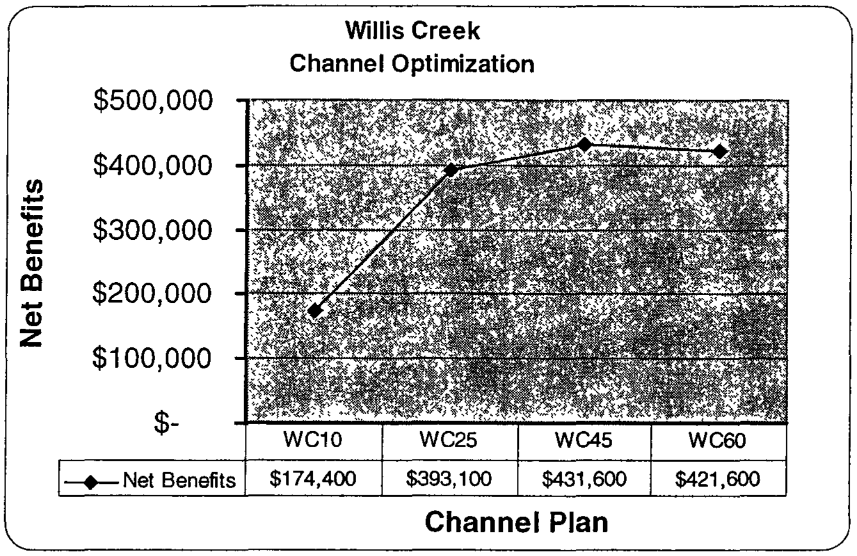


Table 13
Number of Structures Remaining
By Flood Event
With and Without Project

Alternative	10%	4%	2%	1%	0.2%
Existing	144	214	255	274	321
Willis A 10	59	122	201	235	306
Willis B 25	0	39	126	183	284
Willis C 45	0	6	12	30	240
Willis D 60	0	6	10	16	145

Table 14
Number of Structures Removed
By Flood Event
With and Without Project

Alternative	10%	4%	2%	1%	0.2%
Existing	144	214	255	273	321
Willis A 10	85	92	54	39	15
Willis B 25	144	175	129	91	37
Willis C 45	144	208	243	244	81
Willis D 60	144	208	245	258	176

The recommended plan includes the diversion and total and annual project cost of the diversion plan is estimated at $8,270,190 and $574,000, respectively. The resultant BCR is 1.55 to 1.0 with about $313,600 in net benefits. Table 15 presents the economic analysis of the Recommended NED Plan based on an MCASES cost estimate developed in March 2002. Benefits were updated to reflect May 2001 prices and level of development. Table 16 presents the overall project performance accounting for risk and uncertainty. As shown, there is an 87 percent probability that the project would contain the 25-year or 4 percent ACE event. However, it should be recognized that the project is expected to *reduce* overall damages.

Table 15
Economic Analysis of Recommended Plan For Willis Creek

($1000, March 2002 price level)

	WC45 w/Diversion
Estimated First Cost	$8,270,190
Construction Period (Months)	18
Investment Cost	$8,650,121
Operation/Maintenance ($/Year)	$15,600
Total Annual Charges	**$574,000**
Total Annual Benefits	$ 887,600
Net Benefit	**$313,600**
Benefit-to-Cost Ratio	**1.55**

Table 16
Project Performance of Willis Creek Recommended Plan w/Uncertainty

	Expected Annual Target Stage Exceedence Probability		**Long Term Risk (Years)**			**Conditional Non-Exceedence Probability by Event**					
Target Stage	**Median**	**Expected**	**10**	**25**	**50**	**10%**	**4%**	**2%**	**1%**	**.4%**	**.2%**
1358	0.007	0.017	0.158	0.349	0.576	0.985	0.847	0.698	0.594	0.458	0.370

SOCIOECONOMIC EFFECTS OF PLAN IMPLEMENTATION

The potential economic and social effects of implementation of the investigated plan on the study area comprise the value of the long-term reduction in periodic flood damages, and direct and indirect short-term income and employment impacts of project construction.

The permanent reduction in periodic flood damages would effectively increase the income available to flood plain property owners for other purposes, such as (for example) improvements to homes, yards, or personal property. To the extent that this additional disposable income is spent within the surrounding area, it would result in a local "multiplier effect": increases in business revenues, employment, and personal income rippling through the local economy as each new dollar brought in is spent and respent. Property values, and local tax revenues, would also be expected to increase because of an improvement in the condition of the homes and a decrease in the rate of deterioration.

Short-term impacts associated with project construction result from the temporary presence of construction workers in the area and expenditures for construction materials and services. The immediate project area benefits economically from spending by the construction work force for food and other personal needs. These expenditures would, be expected to result in a positive multiplier effect on the local economy.

Given the small scale of the investigated plan, the short-term impacts associated with construction would be temporary and insignificant relative to the overall local economy as a whole. Eventually the only lasting economic and social effects of project implementation would be the benefits resulting from the permanent reduction in flood damages.

Ability-to Pay Analysis. Based on ER 1165-2-121 an ability-to-pay test should be applied to all flood control projects. The test determines the eligibility of the study area to qualify for a reduction in the amount to be cost shared by the Non-Federal interest. To qualify for a reduction the results of both the benefit and income portions of the twofold ability-to-pay test must fall within the specified guidelines.

The benefits' test determines the maximum reduction, called the "benefits based floor" (BBF), in the level of non-Federal cost sharing for any project. The factor is determined by dividing the project B/C ratio 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 WRDA 86 authorized cost share level for the Flood Protection project is 25 percent. The recommended plan's B/C ratio of 1.55 was divided by four to yield a BBF of 0.4 or 40 percent.

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

In accordance with factors released in Economic Guidance 96-4, the income index factors for the state of Texas and Brown County are 90.81 and 102.77, respectively. The Eligibility Factor (EF) for a flood control project is calculated according to the following formula:

$$EF = a - b_1 * (\text{State factor}) - b_2 * (\text{area factor})$$

where:

$a = 15.86794$

$b_1 = 0.06771$

$$b_2 = 0.13543$$

Using the above formula, an EF of -4.2 was calculated for the City of Brownwood. An EF below zero indicates ineligibility for a reduction in construction cost sharing. As stated previously, a BBF factor for the investigated plan was calculated at 50 percent. To qualify for a reduction, the BBF factor must be less than the authorized level of cost sharing in accordance with ER-1165-2-121 paragraph 5a(2). The City of Brownwood does not meet the criteria for a reduction in construction cost since this project meets neither test. Therefore, the City of Brownwood must pay the currently authorized cost share level.

APPENDIX C

REAL ESTATE

APPENDIX C

REAL ESTATE PLAN

PURPOSE

This Real Estate Plan (REP) describes the lands, easements, rights of way, relocations, and disposal areas (LERRD) to be acquired for the Willis Creek Channel Improvement and is submitted under the authority of a Pecan Bayou watershed plan authorized by the Continuing Authorities Program Section 205, previously authorized under Flood Control Act of 1968 (Public Law 90-483) approved 13 August 1968. Citing the above authority, a reconnaissance study was completed in March 1994. Based on the problems and opportunities identified in the March 1994 Reconnaissance Report, flooding is a concern within the Pecan Bayou watershed, particularly along Pecan Bayou and Willis Creek in the city of Brownwood, Texas. The Reconnaissance Report determined that a grass-lined trapezoidal channel of approximately 15,700 feet, with a bottom width of 40 feet, was economically and technically feasible. Subsequently, a cost-shared feasibility study (shared equally between the Government and the city of Brownwood) was initiated in January 1995.

LANDS, EASEMENTS AND RIGHTS-OF-WAY FOR THE RECOMMENDED PLAN

Neighborhood

The project area is located within the limits of the city of Brownwood, Brown County, Texas. The specific project involves improvements to a section of Willis Creek that extends roughly 2.5 miles through southern Brownwood, from Highway 377 South eastwardly to just past Austin Avenue. It traverses several residential subdivisions as well as industrial and commercial areas. The majority of impacted development is residential.

Project Lands

The Willis Creek Channel Improvement Project requires 170.60 acres of LERRD to be obtained. The gross appraisal identified 59 separate tracts existing within the project acreage. Hydraulic enhancements essential to the Willis Creek Channel Improvement Project require 60 acres of Channel Improvement Easement to be obtained. The improvements consist of creating a straighter grass-lined trapezoidal channel with a bottom width of 40 feet. The realigned channel will have a side slope of 1V:3.5H and a depth which will vary between 4 and 11 feet. The improvements will begin at STA 10+00, which is at the existing creek about 200 feet to the south from the west end of Stonebrook Court. The downstream end will be located about 1600 feet east of Quail Creek Court. The alignment of the improvement primarily follows the existing creek, except for several oxbows that are avoided; then rejoins the existing creek just downstream of the oxbows. At STA 78+00, which is 1140 feet downstream of 14th St (F.M. 3064), the alignment diverts from the existing creek and "straight-lines" to the intersection of Willis Creek and 4th Street, which is STA 100+00. The attached map depicts Willis Creek and the required Channel Improvement Easement.

Road Easements totaling 4.1 acres are needed for access to the improved channel for future maintenance. This Road Easement is in three separate areas, as shown on attached map.

A Temporary Work Area Easement for a period of two years is necessary for the project's work staging areas. A work staging area will be located along each of the three access roads. The three staging areas total area is 1.9 acres, as shown on attached map.

Mitigation is necessary due to the reduction of riparian habitat caused by this project. Environmental studies have identified three areas, totaling 104.6 acres, which will serve as mitigation acreage. All properties are unimproved, irregular in shape, and lie completely or partially in the flood plain of Willis Creek.

Table 1 identifies the estates, acreages, and estimated values of the lands.

TABLE 1
LANDS, EASEMENTS AND RIGHTS OF WAY
WILLIS CREEK CHANNEL IMPROVEMENT
BROWNWOOD, TEXAS

ESTATE	ACRES	ESTIMATED VALUE
PROJECT PURPOSE: Flood control		
PROJECT FEATURE: MITIGATION		
Fee	104.6	$329,117
PROJECT FEATURE: CHANNEL IMPROVEMENT		
Channel Improvement Easement	60	$1,947,507
Road Easement	4.1	$68,695
Temporary Work Area Easement	1.9	$4,681

Other LERRD Information

Standard estates in accordance with Chapter 5, ER 405-1-12 will be used for this project. An estate of fee, excepting and subordinating subsurface minerals, is being proposed for the 104.6 acres of mitigation lands.

Sponsor Owned Lands

There are no sponsor-owned lands within the project area.

Existing Federal Projects

There are no existing federal projects within the bounds of the project.

Federally Owned Land

None of the LERRD to be acquired for this project are federally owned.

Navigation Servitude

The LERRD to be acquired for this project are not within the navigational servitude.

IMPACTS ON FLOOD LEVELS

There has been no indication from this study of induced flooding.

BASELINE COST ESTIMATE FOR REAL ESTATE

Property values included in the cost estimate are based on a Gross Appraisal dated February 19, 2001, prepared by Gerald A. Teel Company Inc., 974 Campbell Road, Suite 204, Houston, Texas 77024. Fort Worth District's Planning and Control Branch staff estimated administrative costs. Contingencies have been added to the cost estimate as follows:

01.23.03.01 Real Estate Planning Documents, 10 % based on reasonable certainty.

01.23.03.02 Real Estate Acquisition Documents, 10% based on reasonable certainty of costs.

01.23.03.03 Real Estate Condemnation Documents, 25% based on expectation of at least ten condemnations.

01.23.03.05 Real Estate Appraisal Documents, 25% based on reasonable certainty of contract costs.

O1.23.03.06 Real Estate PL 91-646 Asst. Documents, 10% based on reasonable certainty.

01.23.03.15 Real Estate Payment Documents, based on contingencies assigned by the Appraiser in the Gross Appraisal.

01.23.03.17 Real Estate LERRD Accounting Documents, 25% based on reasonable certainty regarding accounting requirements.

Costs are presented in the following Table 2. Estimates are presented in the standard Code of Accounts from the MCACES Models Database, October 1994.

TABLE 2
REAL ESTATE COST ESTIMATE FOR PROJECT IMPLEMENTATION
WILLIS CREEK CHANNEL IMPROVEMENT
BROWNWOOD, TEXAS

ACCT	DESCRIPTION	ESTIMATE	CONTINGENCY
1	Lands & Damages		
1.23	Construction Contract Documents		
01.23.03	Real Estate Analysis Documents		
01.23.03.01	Real Estate Planning Documents	$8,000	$800
01.23.03.02	Real Estate Acquisition Documents		
	Acquisitions by Local Sponsor	$300,000	$30,000
	Review of Local Sponsor	$6,000	$600
01.23.03.03	Real Estate Condemnation Documents		
	Condemnations by Local Sponsor	$120,000	$30,000
	Review of Local Sponsor	$2,000	$500
01.23.03.05	Real Estate Appraisal Documents		
	Appraisals by Local Sponsor	$72,000	$18,000
	Review of Local Sponsor	$12,000	$3,000
01.23.03.06	Real Estate PL 91-646 Asst. Documents		
	PL 91-646 Asst. by Local Sponsor	$5,000	$500
	Review of Local Sponsor	$1,000	$100
01.23.03.15	Real Estate Payment Documents		
	Payments by Local Sponsor	$1,904,236	$445,764
	PL 91-646 payments made by local sponsor	$10,000	$2,500
	Review of Local Sponsor	$2,000	$500
01.23.03.17	Real Estate LERRD Accounting Documents	$13,000	$3,250
	TOTAL ADMIN & PAYMENTS	$2,455,236	
	TOTAL CONTINGENCY		$535,514
	GRAND TOTAL	$2,990,750	

DISPLACEMENT OF PERSONS, FARMS OR BUSINESSES

The project does not necessitate the relocation of any residences. Although no persons or businesses will be affected, a number of small outbuildings are within the lands to be acquired. Nominal funding for PL 91-646 assistance has been estimated for the removal of personal effects within outbuildings.

MINERALS AND TIMBER

The 104.6 acres to be acquired for project mitigation is fee, excepting and subordinating subsurface minerals. There is no mineral activity in the urbanized area. Current zoning restrictions also prohibit the extraction of minerals in and around the project area. There is no significant amount of merchantable timber within the subject area.

NON-FEDERAL SPONSOR'S CAPABILITY TO ACQUIRE LERRD

The City of Brownwood is proposing to acquire LERRD. A checklist has been prepared in accordance with Chapter 12 of ER 405-1-12 and is included at the end of this real estate plan. The City has been advised of the requirements of Public Law 91-646, as amended, and the requirements for documenting expenses for credit purposes. The City has been advised in writing of the risks associated with acquiring LERRD before execution of the PCA. The Corps will work with the sponsor throughout the project, to the extent appropriate and allowable, to assure that there is understanding of the Federal real estate principles. Action will also be taken to address policy issues along the way that could significantly affect the project.

PROPOSED ZONING

There are no proposals to enact new zoning in lieu of, or to facilitate, LERRD acquisition.

MILESTONES FOR REAL ESTATE ACQUISITION

The following table contains milestone schedules for real estate acquisition, which begins with the scheduled signing of the Project Cooperation Agreement.

TABLE 3
REAL ESTATE COST ESTIMATE FOR PROJECT IMPLEMENTATION
WILLIS CREEK CHANNEL IMPROVEMENT
BROWNWOOD, TEXAS

ACTIVITY	COE INITIATE	COE COMPLETE	LS INITIATE	LS COMPLETE
Execution of PCA	--	30 Apr 2004	--	15 Apr 2004
Transmittal of ROW drawings to LS with instruction to acquire LERRD	--	30 Apr 2004	--	--
Conduct landowner meeting	--	--	--	30 Jun 2004
Prepare mapping and legal descriptions	--	--	1 May 2004	31 Aug 2004
Review mapping and legal descriptions	1 Sep 2005	30 Sep 2005	--	--
Obtain title evidence	--	--	1 Mar 2003	31May 2003
Review title evidence	1 June 2003	15 June 2003	--	--
Obtain tract appraisals	--	--	1 Mar 2003	30 Jun 2003
Review tract appraisals	1 Jul 2003	31 Jul 2003	--	--
Conduct negotiations	--	--	1 Aug 2003	1 Apr 2004
Perform closings	--	--	30 Aug 2004	15 Jan 2005
Prepare condemnations	--	--	30 Aug 2004	15 Dec 2004
Review condemnations	--	--	31 Sep 2004	31 Dec 2004
Perform condemnations	--	--	30 Aug 2004	15 Jan 2005
Obtain possession	--	--	15 Jan 2005	28 Feb 2005
Complete PL 91-646 benefit assistance	--	--	--	15 Mar 2003
Review PL 91-646 payments	--	30 Apr 2003	--	--
Certify availability of LERRD	20 Apr 2005	30 Apr 2005	15 Apr 2005	20 Apr 2005
Prepare and submit credit requests	--	--	20 Apr 2005	20 May 2005
Review credit requests	20 May 2005	15 Jun 2005	--	--
Approve or deny credit requests	15 Jun 2005	15 Jun 2005	--	--
Establish value of LERRD credit in accounting records	15 Jun 2005	30 Jun 2005	--	--

RELOCATIONS OF UTILITIES OR FACILITIES

Reference Appendix A, sub-Appendix C, Civil Design with regard to any roads or utility relocations. According to the Attorney's Opinion obtained April 16, 2001, prepared by Kenneth H. Price, Real Estate Division Staff Attorney, relocation of all utility lines will be the responsibility of the project sponsor because none of the lines fall within the public right-of-way. If a utility is operating within a public right-of-way, it is usually under a license. If so, the utility must relocate at it's own expense because it has lost no property rights even though it incurs costs as a result of the forced relocation. Consumers Power Co. v. Costle, 615 F2d 1147 (6th Cir 1980). Cost estimates for the relocation of utility lines can be found in Appendix A, sub-Appendix H, Cost Engineering.

LANDS CONTAINING HAZARDOUS WASTE

None of the project LERRD are known to contain hazardous, toxic or radiological waste (HTRW). Reference Appendix A, sub-Appendix E of the Feasibility study for detailed analysis of HTRW investigation.

LANDOWNER RESPONSE TOWARD THE PROJECT

The Willis Creek Channel Improvement Project has been highly publicized within Brownwood. Public meetings have been held and the overall reaction of the community has been favorable.

OTHER REAL ESTATE ISSUES

No other issues relevant to the planning, design, or implementation of this project are known.

CESWF-RE-P (405-10f) 29 June 2001

MEMORANDUM FOR RECORD

SUBJECT: Assessment of the Real Estate Acquisition Capability of **The City of Brownwood** in accordance with CERE-AP Memorandum, dated 2 May 1996, Subject: Real Estate Policy Guidance Letter No. 12 -- Capability Assessments of Potential Non-Federal Sponsors of Cost-Shared Civil Works Projects

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? **YES**

b. Does the sponsor have the power of eminent domain for this project? **YES**

c. Does the sponsor have "quick-take" authority for this project? **NOT APPLICABLE**

d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? **YES- There are two areas that lie outside the sponsor's city limits. One of these areas is in the process of being annexed. The other will have to be condemned with the help of the county of Brownwood.**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **No**

II. Human Resource Requirements:

a. 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** The City Planer is attending an August class which covers federal real estate acquisition.

b. If the answer to II.a. is yes, has a reasonable plan been developed to provide such training? **YES**

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **YES**

d. Is the sponsor's projected in-house staffing level sufficient considering other work load, if any, and the project schedule? **YES**

e. Can the sponsor obtain contractor support, if required, in a timely fashion? **YES**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **NO**

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? **YES**

b. Has the sponsor approved the project/real estate schedule/milestones? **YES**

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? **NOT APPLICABLE**

b. With regard to this project, the sponsor is anticipated to be: **MODERATLY CAPABLE**

V. Coordination:

a. Has this assessment been coordinated with the sponsor? **YES**

b. Does the sponsor concur with this assessment? **YES**

Prepared by:

Blake Bryant
Realty Specialist

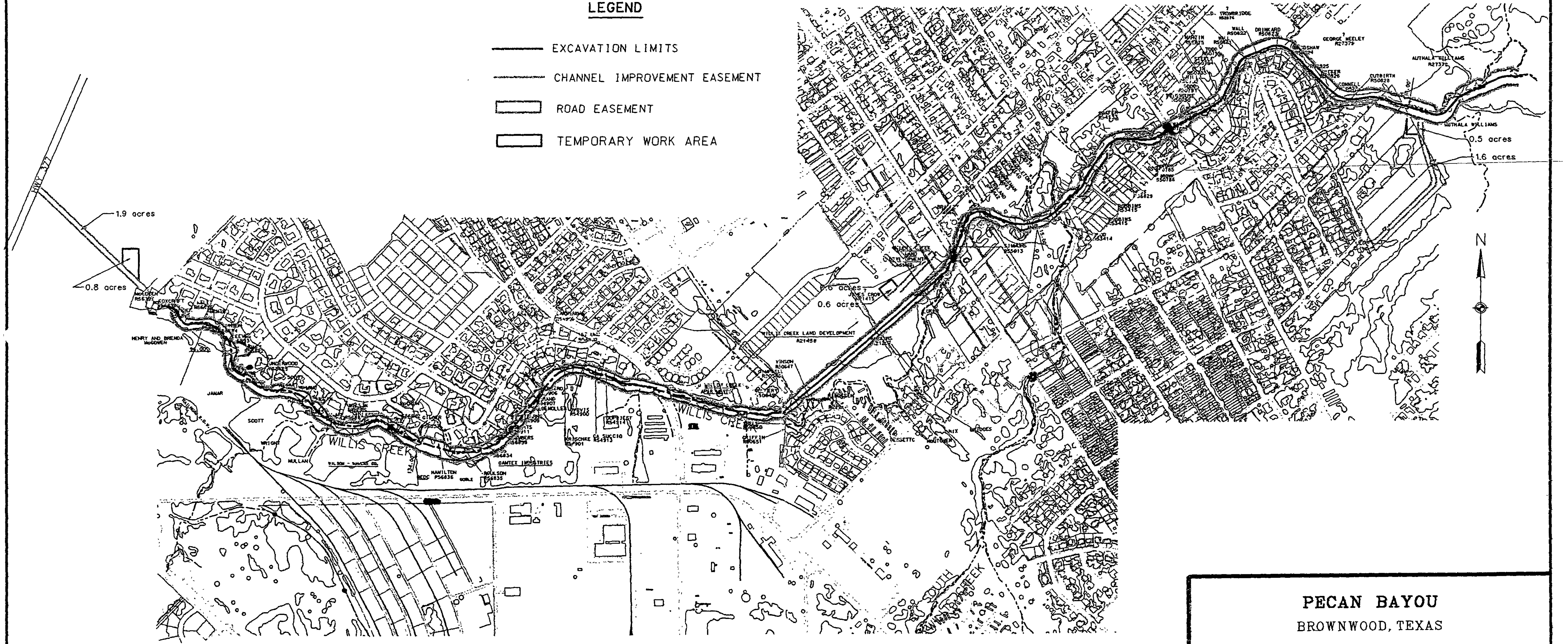
Reviewed and approved by:

Hyla J. Head
Chief, Real Estate Division

CHANNEL IMPROVEMENT .... 60 ACRES
EASEMENT

TEMPORTY WORK AREA .... 1.9 ACRES

ROAD EASEMENT...............4.1 ACRES



LEGEND

———	EXCAVATION LIMITS
- - - -	CHANNEL IMPROVEMENT EASEMENT
▭	ROAD EASEMENT
▭	TEMPORARY WORK AREA

PECAN BAYOU
BROWNWOOD, TEXAS

WILLIS CREEK
CHANNEL IMPROVEMENT

REAL ESTATE

APPENDIX D

CULTURAL ANALYSIS

APPENDIX D

CULTURAL RESOURCES

INTRODUCTION

The proposed undertakings in this feasibility study have been examined for the potential to impact cultural resources within the Pecan Bayou, Adams Branch and Willis Creek project areas located in Brownwood, Brown County, Texas. Cultural resources can be defined as the broad pattern of events, real properties, and cultural lifeways or practices, that have significance to humans. These can be buildings and places where significant events occurred, archeological sites where evidence of human activity exists, places that hold special significance to traditional societies or groups of people, and folkways or traditional activities which are practiced as either cultural or life sustaining features of groups of people. The U.S. Army Corps of Engineers, Fort Worth District (CESWF), considers all of its impacts and possible effects prior to any construction and systematically establishes a strategy to account for, avoid when possible, and provide for a mitigative strategy on unavoidable significant impacts to, cultural resources.

The project undertaking for Pecan Bayou was not defined and because this alternative is no longer being evaluated, no further cultural resources investigations were completed and no further discussion of any potential impacts for Pecan Bayou are presented here. The proposed undertaking for the Adams Branch project area is the excavation of an off-channel segment from the upper portion of the branch near Highway 377 as it enters Brownwood on the northeast, extending across an existing agricultural area for approximately 8,600 feet (2,621 meters) to join the existing tributary of Pecan Bayou. The Willis Creek undertaking consists of the principally of the channelization of two sections of the creek along with the addition of an off-channel swale for overflow events. The first, or upper segment, extends from east of Highway 377 near the southwest part of Brownwood for approximately 7,000 feet to a point where an off-channel segment will begin. The off-channel segment crosses a parcel of land for 1,500 feet to rejoin the Willis Creek as it flows under the 4th Street Bridge. The existing segment of Willis Creek between the approximately 7,000 foot point and the 4th Street Bridge will not be modified. Below the 4th Street Bridge, the off channel segment will continue for approximately 1,000 feet, rejoining the existing Willis Creek channel alignment at the point where South Creek joins Willis Creek. The existing Willis Creek channel will be channelized from below the 4th Street Bridge for approximately an additional 6,500 feet, ending about 1,700 feet upstream of the existing water treatment plant.

The cultural resources component of these proposed undertakings for the Adams Branch and Willis Creek project areas considers all of the legal responsibilities and obligations of CESWF, with respect to all applicable cultural resources laws, Executive Orders, Presidential Memoranda, and U.S. Army Corps of Engineers Regulations, including, but not limited to: the *National Historic Preservation Act* (NHPA) *of 1966* (Public Law (PL) 89-665 *et seq.*), the *National Environmental Policy act* (NEPA) *of 1969* (PL 90-190 *et seq.*), the *Native American Graves Protection and Repatriation Act* (NAGPRA) *of 1990* (PL 101-601), Executive Order 13007 (*Accommodation of Sacred Sites* - 24 May 1996), *Government-to-Government Relations with Native American Indian Tribal Governments* (Presidential Memorandum of 29 April 1994), and Engineer Regulation (ER) 1105-2-100 (*Planning Guidance Notebook*).

No previous cultural resources inventory or assessment effort has been completed within the project areas and no intensive field effort was undertaken for this feasibility study. A reconnaissance visit to the project areas was completed in 1997 by a staff archeologist from CESWF that indicated that the potential for encountering archeological properties in both project areas was high. Properties of an architectural or engineering nature may be present as well but are unknown at this time because no inventory or assessment was completed for those types of properties as well. Both study areas will require additional investigations in order to assess any impacts to cultural resources prior to construction. For purposes of compliance with the NHPA, cultural resources compliance issues for the two project areas are being addressed through ongoing consultation with the office of the Texas State Historic Preservation Officer (TXSHPO). Impacts to other cultural resource properties will be addressed through ongoing consultation efforts with affected Native American Indian tribes and other groups.

EXISTING CONDITIONS

Cultural Resources Considerations

As discussed earlier, cultural resources can be defined as the broad pattern of events, real properties, and cultural lifeways or practices, that have significance to humans. Buildings and places where significant events occurred, archeological sites containing significant information about human activities, traditional places or activities that hold special significance, and folkways which are practiced as either cultural or life sustaining, are all part of the broad category features of groups of people. The majority of cultural resources within the Adams Branch and Willis Creek project areas will be properties of an archeological nature consisting principally of the traces of prehistoric and historic peoples, and those properties that are standing structures. These types of historic properties are usually considered for eligibility or listing in the *National Register of Historic Places* (NRHP). Section 106 (16 U.S.C. 470*f*) of the NHPA requires that Federal agencies consider their undertakings, or projects, and the potential of those undertakings to impact NRHP eligible or listed properties through the procedures found in 36 CFR Part 800 (*Protection of Historic Properties*). These consultations must include the Texas State Historic Preservation Officer (TXSHPO) and, where additional parties with a demonstrated interest in the outcome of such consultations are identified, other parties such as historic preservation groups, archeological societies, traditional groups (including Native American Indian tribes), and individuals. CESWF should begin consultation early to identify all interested parties and to notify the TXSHPO of the proposed project undertakings.

Native American Indian cultural resource concerns and issues may involve NRHP properties and those issues will be addressed as part of the 36 CFR Part 800 consultations. However, other cultural resources of significance to Native American Indian tribal groups such as inhumations or human burials, whether intentional or by natural means, and sites of cultural significance because of an extensive historical cultural use for culture sustaining activities, will need to be addressed separately. While the probability of impacting such properties is slight, the appropriate course of action for CESWF is to begin consultations on appropriate measures or steps to be taken if such a discovery were made during a project undertaking. Native American Indian burials are subject to the considerations of NAGPRA when a Federal project impacts such remains on lands owned fee simple by the government or are in the substantive legal control of the government through leases or easements. No properties of culturally sustaining significance have presently been identified by any historically associated Native American Indian tribal group as occurring within the project areas. Consultations with affected tribal organizations and their appropriate representatives will be utilized to assist with assessing project impacts to any unidentified practices or sites.

General Overview

The project areas in general have had only marginal previous inventory efforts for cultural resources and none within the specific project footprints or areas of potential effect. Only one potential archeological site has been identified as existing within the off channel project footprint for the Adams Branch. Prehistoric material was noted during the construction of a detention pond on the US Department of Agriculture Pecan Research Center from a depth of five to six feet below the ground surface. The site was not recorded and no further investigation occurred. All of the systematic study efforts conducted in the region focused on properties of an archeological nature only and did not record standing buildings or structures. Other survey efforts have been completed within a geographical proximity to the project areas that can provide a general overview of the types of resources that could be encountered. The majority of these resources have been prehistoric archeological sites which are generally located near, or adjacent to, the major tributaries of the area or along the interfluvial ridges. Standing historic structures and buildings may be present within the project areas and will typically be associated with older homes and possible business buildings, and could include existing bridges which may be located across both Willis Creek or the upper end of the Adams Branch off-channel segment.

Some early efforts in Brown County date back to 1919 when J.E. Pearce, Ph.D., of the University of Texas excavated two burned rock middens along Willis Creek about two miles west of the upper project area (Campbell 1952). In 1933 a burial associated with a rockshelter was reportedly destroyed during highway construction in Brownwood (Ray 1933). Other early efforts were generally reporting of sites by avocationalists and archeological societies (Patterson 1936; Poteet 1938). More recent efforts include the surveys of portions of the upper Pecan Bayou watershed (Shafer et al. 1975a), the Brownwoods laterals watersheds (Shafer et al. 1975b), and the testing of several sites on a tributary of the Pecan Bayou (Shafer et al. 1976). In 1977 George Kegley (no publication) recorded a single site south of the Willis Creek project area along a small tributary leading to Willis Creek. In 1978 and 1980 Hayden Whitsett recorded eight archeological properties on Willis Creek and Pecan Bayou near their confluence just downstream of the Brownwood water treatment plant (Whitsett 1980). In 1987 the Travis County Archeological Society recorded six additional archeological properties in the same area, two of which were historic period cemeteries (no publication). In 1992, Nancy Mottashed Cole surveyed a portion of Adams Branch as it meanders through downtown Brownwood but recorded no archeological properties (Cole 1992). The surveyed portion of Adams Branch ends before reaching the project area for the Adams Branch off-channel alignment. Other survey and inventory efforts have been completed in and around Brownwood but are not directly relevant to the defined project areas and will not be discussed here.

None of the archeological sites nearest the project areas have had the criteria for listing in the NRHP applied but the majority of the sites recorded were reported as have some integrity and some were reported as having significant depth. The nature of the previous archeological findings for Willis Creek and Pecan Bayou surveys and one archeological testing project indicate that buried sites are likely in areas of major confluences and along tributaries where bluffs and rockshelters are present. Also likely to have a potential for archeological resources are terraces adjacent to the tributaries which were better watered historically and in areas where lithic sources are available, such as the east bank of the Pecan Bayou just south of Willis Creek. In areas of frequent flooding and overbank deposition such as along the Adams Branch off-channel project area, in the floodplain areas of Willis Creek, and at the confluence of the Pecan Bayou with Willis Creek, buried to deeply buried prehistoric sites are highly probable. The likelihood of historic period archeological sites within the project areas appears marginal and the available historic data does not indicate the previous existence of buildings within the immediate project areas from an earlier period. Some historic data does indicate earlier historic structures in the vicinity of the confluence of Pecan Bayou and Willis Creek, possibly associated with the earliest settling of Brownwood, but no exact plats are available at this time.

No historic standing buildings or structures (homes, businesses, bridges, or other constructed or engineered properties) have been previously identified near or adjacent to the present project areas. While an inventory has not been completed for any of the project areas to determine the existence of standing historic buildings and structures, including any bridges crossing the project areas, the potential for such properties within the areas of potential effect exists. The project area will require individual inventorying and possibly an NRHP assessment depending on the age, context, and design of the properties.

PROJECTS and ALTERNATIVES

This portion of the feasibility study utilizes the currently known cultural resources information for the two project areas as identified above and broadly analyzes it against the implementation of the proposed projects on a local and regional impact scale. Potential adverse effects are noted according to the potential project undertaking.

Adams Branch

Alternative 1. No Action Plan

No action on the off channel construction will have no impact on cultural resources.

Alternative 2. National Economic Development Plan

The alternative selected for the Adams Branch improvement is an 8,500 foot long, ten foot bottom width grass lined channel, which will be excavated through the plain just east of the existing branch. The top width will be approximately sixty feet wide and approximately five to seven feet deep, being shallower on the southern end. The channel will diverge from Adams Branch on the northern end near Highway 377 as the highway enters Brownwood, extending southward until merging with the existing Pecan Bayou channel. The channel will be placed in an area of significant flood deposition and soils accumulation making it a high probability for impacting buried cultural resources in this project area. Given that a report of prehistoric material was previously noted at five to six feet below the surface during construction of the detention pond on the USDA research site, it is likely that prehistoric archeological sites will be present. The southern end of the off-channel as it nears the entry point with the existing Pecan Bayou is also likely to encounter buried prehistoric resources anywhere along its margins. No standing structures or buildings have been noted within the project area that could be impacted by the planned undertaking and, unless modifications to the existing bridge at Highway 377 are required, it is unlikely that any building or structure inventory is required.

Alternative 3. Locally Preferred Plan

The locally preferred plan (LPP) is the same as the NED plan at this time therefore the potential impact to cultural resources are the same for both plans.

Willis Creek

Alternative 1. No Action Plan

No action on the channel modification of the existing creek will have no impact on cultural resources.

Alternative 2. National Economic Development Plan

The alternative selected for the Willis Creek project area is the channelization of two sections of the creek along with the addition of an off-channel swale for overflow events. All channels and the swales will be approximately 45 feet in bottom width and approximately 100 at the top width. The first, or upper segment of the channel, extends from east of Highway 377 near the southwest part of Brownwood for approximately 7,000 feet to a point where an off-channel segment will begin. The off-channel segment crosses a parcel of land for 1,500 feet to rejoin the Willis Creek as it flows under the 4th Street Bridge. The existing segment of Willis Creek between the approximately 7,000 foot point and the 4th Street Bridge will not be modified. Below the 4th Street Bridge, the off channel segment will continue for approximately 1,000 feet, rejoining the existing Willis Creek channel alignment at the point where South Creek joins Willis Creek. The existing Willis Creek channel will be channelized from below the 4th Street Bridge for approximately an additional 6,500 feet, ending about 1,700 feet upstream of the existing water treatment plant. The proposed modifications are likely to impact potential prehistoric and possibly historic archeological sites in all of the component areas and could also impact unidentified standing historic properties as well. The lower reach of Willis Creek nearest the confluence with Pecan Bayou will be of particularly high sensitivity for impacts to archeological properties as several archeological sites have already been identified in the area south of the water treatment plant. The project areas just upstream of the water treatment plant as well as the remaining project areas along Willis Creek are expected to have similar sensitivity. Several standing structures and buildings located within or adjacent to the project areas could also be adversely impacted depending on the need to remove or modify any of these structures or the adjacent landscape. Increased waterflow velocities from the channelization of the upper portion of Willis Creek through the unimproved middle portion of the drainage could cause unintended erosion to the middle portions of the creek and therefore adversely impact archeological or other properties.

Alternative 3. Locally Preferred Plan

The LPP is the same as the NED plan at this time therefore the potential impact to cultural resources are the same for both plans.

EVALUATION AND RECOMMENDATIONS

Evaluation

Only extant data and available historical documents were reviewed during this feasibility study for the two project areas. No effort to notify interested or consulting parties, conduct extensive background overview documentation, or investigative efforts to identify cultural or historic resources, was undertaken as part of the feasibility effort. All cultural resources coordination, consultation, field investigations, and other efforts, will need to be conducted prior to any construction, preferably prior to the final design and specification phase for these projects in order to minimize design changes or delays created by mitigation responsibilities.

Consultation with Native American Indian tribes culturally affiliated with the geographic region of Brownwood has not occurred. Presently, nothing has been defined which could represent a traditional cultural property of significance, including culturally sustaining properties and those properties of possible NRHP eligibility, to Native American Indian tribal groups. The likelihood of Native American Indian culturally sustaining properties being encountered in the project areas is improbable. Any historic properties identified during planned survey and inventory efforts which possibly NRHP eligible, will require further consultation with tribes on the impacts to those sites.

All overview information reviewed, and previous cultural resource efforts conducted in the general vicinity of the proposed project area of Brownwood, indicates a high potential for encountering archeological sites, probably prehistoric in nature, within the currently identified specific project areas of the off-channel alignment along Adams Branch and throughout the entire portion of the Willis Creek project area. A limited site visit by a US Army Corps of Engineers, Fort Worth District, staff archeologist reported that several areas appeared to have high potential for buried resources and should be investigated prior to project undertakings. The proposed extensive excavation to widen the Willis Creek drainage and the construction/excavation of the off-channel segment for Willis Creek has a high potential to impact moderately to deeply buried prehistoric archeological resources. The widening of the creek and the excavation of the off-channel segment for Willis Creek also has the potential to impact unrecorded historic period archeological resources. The off-channel segment for the Adams Branch project also has a high potential to impact moderately to deeply buried prehistoric archeological resources and significantly so nearer the southern portion of the proposed channel near Pecan Bayou. Any portion of either project which could impact archeological resources would require additional consultation on those effects, an assessment of NRHP eligibility, and potentially, a mitigative effort designed to preserve the significance of any NRHP eligible archeological sites encountered.

Some 19th and early to middle 20th century historic structures are reported as present in the area in the immediate project area of the Willis Creek undertaking, but their specific relationship or proximity to the undertaking has not been ascertained. Similarly, nothing is known about the bridges that cross the Willis Creek and Adams Branch project areas. Additionally, nothing has been defined as to any proposed buyouts of existing buildings or possible bridge modifications that would be required for project purposes. An inventory, evaluation and assessment of all buildings and structures within the project areas of potential effect is required. Buildings and structures determined in consultation to be NRHP eligible and which cannot be avoided by design changes will require continued consultation to determine ways to avoid impacts or define mitigative strategies.

Recommendations

CESWF should initiate consultation with the TXSHPO to begin the identification of the areas of potential effect and to determine the level of effort required to identify historic properties within the project areas. CESWF should also initiate consultation with Native American Indian tribes culturally affiliated with the region and any other parties which express a desire to be consulting parties per 36 CFR Part 800. Native American Indian tribes as well as other traditional groups should be consulted to determine the existence of potential culturally sustaining properties within the project areas. Cultural resources survey and inventory investigations designed to meet the requirements of Section 106 of the NHPA should be accomplished as early as possible in the design phase in order to allow for appropriate changes to avoid identified historic properties. Potential historic properties discovered during the survey and inventory effort will require consultation with the TXSHPO, and other consulting parties, on the original identification as well as the plan on avoidance, and on any mitigative strategies identified. Deferral in conducting the cultural resources investigations could create project construction delays resulting from late design changes to avoid historic properties, or possibly significant delays as consultation, additional archeological site testing, and possibly, mitigation efforts are completed on historic properties that cannot be avoided. Historic properties, which cannot be avoided and must be mitigated, would likely incur significant additional costs beyond those estimated in this document.

This recommendation does not include proposing archeological monitoring during construction activities because of the delays that could occur if an archeological property is identified. Any suggestion of monitoring during construction for impacts to buildings or structures will be unacceptable to the TXSHPO because those properties must be identified prior to construction activities. If a design or realignment change could not be made into an area previously investigated and determined to be absent any type of cultural resources or historic properties, additional investigation would be required before the new alignment could be made. An inability to alter the design or realign would require consultation on the NRHP eligibility of the properties discovered, possible including further field investigations, and, pending an NRHP eligible determination, would require additional consultation and efforts to mitigate any significant archeological sites.

Significant NRHP eligible archeological properties identified during the survey and inventory effort will likely require a mitigation effort if design changes or realignments are not possible. Given the current potential, pending actual field investigative and identification efforts, for archeological sites in the project areas, it is likely that any archeological mitigation efforts in either project area could exceed the one per cent of project cost limitation as specified in Section 7a of Public Law 93-291 (16 USC 469). As defined in the PGN (ER 1105-2-100, Appendix C.4.b(10)), the one percent limitation is only applicable to mitigation efforts associated with data recovery from archeological sites and does not include survey, inventory, assessment, testing, associated consultation, building or structure mitigation, real estate or engineering costs. Section 208 of the NHPA Amendments of 1980 authorizes data recovery in excess of the one percent level when the Assistant Secretary of the Army (Civil Works) seeks the concurrence of the Secretary of the Interior (through the Departmental Consulting Archeologist) and notification of Congress. For Continuing Authorities Projects, Corps Commands shall use the waiver process described in ER 1105-2-100, Appendix C.4.d(6)(c)), submitting the waiver request through channels to the Corps Federal Preservation Officer (FPO), who shall serve as the headquarters technical specialist and liaison. The FPO will review the waiver request, coordinate with all appropriate headquarters elements, and submit the request to the Secretary of the Interior, through the National Park Service Departmental Consulting Archeologist, for concurrence and Congressional notification. The request will require supporting documentation a detailed justification for the need to exceed the one percent level.

In summary, the project areas may contain the potential for the presence of moderately and deeply buried archeological properties. The hydraulic channel improvement alternative will not have any affect on any historic structures. The area does however, exhibit significant alluvial deposition and the potential for archaeological sites to be buried within this alluvium is extremely high. This potential exists wherever the channel may be placed. A cultural resources survey and backhoe trench subsurface testing of the alluvial deposits for possibly buried archaeological sites will be necessary during the next phase of project development. If significant archaeological sites are encountered during this survey and subsurface testing, then these sites will need to be avoided or mitigated through data recovery. As a result, CESWF should begin immediate consultation with the TXSHPO and other consulting parties on the identification of the project's area of potential effects and an acceptable field methodology to be employed as part of the identification process. Contingent if any significant properties are identified, additional consultation on possible effects to potentially eligible or listed NRHP properties will be required to meet the provisions of NHPA Section 106 requirements. All potential impacts to cultural resources will be considered as part of the project planning and will be systematically avoided or appropriately mitigated prior to project execution.

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APPENDIX E

PROJECT MANAGEMENT PLAN

APPENDIX E

PROJECT MANAGEMENT PLAN
FOR
PLANS AND SPECIFICATIONS

Willis Creek Channel Improvement
Pecan Bayou Lake, Brownwood, Texas

INTRODUCTION

This Project Management Plan (PMP) has been developed to plan, define, and control the completion of the plans and specifications phase of the project. The PMP describes the responsibilities of the Government in completing the plans and specifications, and will be used as a mechanism to measure progress and performance of all the plans and specifications phase efforts.

PLANS AND SPECIFICATIONS SCOPE OF WORK

Hydrology and Hydraulics

During the plans and specifications phase of the project, specific reaches of channelization requiring bottom and/or side slope protection via rip-rap lining and/or gabion baskets, etc. will be identified. Details for small berms to direct low flows into the otherwise cut-off oxbows will be developed. The most cost effective means of enlarging two sets of box culvert crossings located at Fourth Street (Southside Drive) and at Fourteenth Street (Custer Road) will be carefully verified through cooperation with the Structural Engineering Section. Details for channel approaches and exits at the roadway crossings (Austin Avenue, Fourth Street, and Fourteenth Street) will be developed. Acceptability (from a flood control standpoint) of selected, site-specific alterations in the current channel alignment or section shape will be verified. A pilot channel will be developed with the cooperation of the Civil Engineering Section and the Environmental Resources Section. As an option (for the City of Brownwood), a package revising the current Flood Insurance Study will be prepared and submitted to FEMA.

Major Task	Responsible Party	Hours	Man-Rate	Hourly-Total Cost
Bottom and/or Side Slope Protection Design	CESWF-EC-DH	80	$ 78.00	$ 6,240
Berm Details Design	CESWF-EC-DH	40	$ 78.00	$ 3,120
Enlargement of Box Culvert Crossings	CESWF-EC-DH	24	$ 78.00	$ 1,872
Channel Approaches and Exits Design	CESWF-EC-DH	40	$ 78.00	$ 3,120
Verify Current Channel Alterations	CESWF-EC-DH	40	$ 78.00	$ 3,120
Pilot Channel Design	CESWF-EC-DH	24	$ 78.00	$ 1,872
Option – Revise Flood Insurance Study	CESWF-EC-DH	120	$ 78.00	$ 9,360
Total Hydrology and Hydraulics				***$ 28,704***

Civil Engineering

During the plans and specifications phase of the project, field trips and project meetings will be conducted to ensure compliance with the project scope and the user's desires. Design work will include data collection, quantity takeoffs, and the preparation of detailed engineering drawings and specifications. The incorporation of review and BCO comments will include response to and compliance with comments, providing final plan adjustments and final bid schedule quantities, correcting drawings, and preparing final documents and specifications.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Design - 95% Submittal:				
Field Trip; Meetings	CESWF-EC-DC	8	$ 80.00	$ 640
Data Collection	CESWF-EC-DC	32	$ 80.00	$ 2,560
Layout of Selected Plan	CESWF-EC-DC	80	$ 80.00	$ 6,400
Quantity Takeoff	CESWF-EC-DC	16	$ 80.00	$ 1,280
Drawing Preparation-				
Layout Project	CESWF-EC-DC	40	$ 80.00	$ 3,200
Final Documents	CESWF-EC-DC	40	$ 80.00	$ 3,200
Specifications Preparation	CESWF-EC-DC	24	$ 80.00	$ 1,920
Review and BCO Comments :				
Field Trip; Meetings	CESWF-EC-DC	4	$ 80.00	$ 320
Respond to Comments	CESWF-EC-DC	16	$ 80.00	$ 1,280
Final Plan Adjustments	CESWF-EC-DC	16	$ 80.00	$ 1,280
Final Bid Sch. Quantities	CESWF-EC-DC	8	$ 80.00	$ 640
Drawing Correction	CESWF-EC-DC	8	$ 80.00	$ 640
Final Document Preparation	CESWF-EC-DC	16	$ 80.00	$ 1,280
Finalize Specifications	CESWF-EC-DC	8	$ 80.00	$ 640
Supervision	CESWF-EC-DC	24	$100.00	$ 2,400
CADD Support	CESWF-EC-D	na	na	$ 2,500
Total Civil Engineering				***$ 30,180***

Utility, Road, and Bridge Relocations

During the plans and specifications phase of the project, all under or above ground utilities (water, sewer, electrical, telephone, cable, natural gas, etc.), railroads, roads, and bridges will be identified and appropriate data will be collected to identify those conflicts which will require relocation. Design and construction of relocations necessary to accommodate the project will be the responsibility of the Sponsor, with the exception of railroad bridges, which are the responsibility of the Government. If the Sponsor requests that the Government provide the design and/or construction of the relocations, then the Sponsor will be responsible for appropriate reimbursement of those items of work.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Design Coordination:				
Field Trip; Meetings	CESWF-EC-DC	8	$ 80.00	$ 640
Data Collection	CESWF-EC-DC	16	$ 80.00	$1,280
Coordination with Facility Owner	CESWF-EC-DC	8	$ 80.00	$ 640
Identify Utility and Bridge Conflicts	CESWF-EC-DC	16	$ 80.00	$ 1,280
Review Coordination:				
Field Trip; Meetings	CESWF-EC-DC	4	$ 80.00	$ 320
Verify Facility Owner Right-of-Way Easement	CESWF-EC-DC	8	$ 80.00	$ 640
Supervision	CESWF-EC-DC	12	$100.00	$1,200
CADD Support	CESWF-EC-DC	na	na	$ 600
Total Relocations				***$ 6,600***

Structural Engineering

During the plans and specifications phase of the project, project features requiring concrete such as channel paving, or other materials involving structural engineering will be developed in detail, including the estimation of quantities. Detailed engineering and design will be completed to include all analysis and development of engineered drawings and specifications. The engineered drawings will include all plan views, elevations, sections, and details to enable prospective contractors to submit bids on the drawings and specifications. The plans and specifications will be utilized by the contractor to construct the project.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Plans and Specifications:				
Sections, Details, and Specifications	CESWF-EC-DS	200	$ 85.00	$ 17,000
Compute Quantities	CESWF-EC-DS	24	$ 85.00	$ 2,040
Prepare Structural Analysis	CESWF-EC-DS	40	$ 85.00	$ 3,400
Meetings/Coordination	CESWF-EC-DS	16	$ 85.00	$ 1,360
Supervision and Administration	CESWF-EC-DS	10	$100.00	$ 1,000
Travel, Per Diem	CESWF-EC-DS	na	na	$ 750
CADD Support	CESWF-EC-D	na	na	$ 2,500
Total Structural Engineering				***$ 28,050***

Agronomy

During the plans and specifications phase of the project, the requirements for the reestablishment of turf on all areas anticipated to be disturbed by construction of the project shall be documented. This will include the identification of plant species, planting period, and maintenance.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Field Trip; Meetings	CESWF-EC-DC	16	$ 75.00	$ 1,200
Turfing Layout Plans	CESWF-EC-DC	16	$ 75.00	$ 1,200
Quantity Takeoff	CESWF-EC-DC	8	$ 75.00	$ 600
Drawing Preparation –				
Layout Project	CESWF-EC-DC	8	$ 75.00	$ 600
Final Documents	CESWF-EC-DC	16	$ 75.00	$ 1,200
Specifications Preparation	CESWF-EC-DC	16	$ 75.00	$ 1,200
ITR	CESWF-EC-DC	4	$ 75.00	$ 300
Incorporate Comments	CESWF-EC-DC	4	$ 75.00	$ 300
Supervision	CESWF-EC-DC	8	$100.00	$ 800
CADD Support	CESWF-EC-D	na	na	$ 650
Total Agronomy				***$ 8,050***

Geotechnical Engineering

During the plans and specifications phase of the project, a field investigation to include drilling additional borings to further delineate the top of rock for excavation quantity estimates along the Willis Creek project alignment, will be conducted. No testing is required, just visual classification of soil and rock types encountered in the borings. Plan sheets (CADD plan and profile drawings depicting borings drilled along the project alignment) and technical specifications will be prepared. All P&S documents will be reviewed. Responses to BCO and review comments will be prepared. Both comments and responses will be reviewed by supervisory personnel.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Field Investigation	CESWF-EC-DG	na	na	$ 11,000
Plans and Specifications:				
Preparation of Drawings And Specifications	CESWF-EC-DG	173	$ 53.00	$ 9,169
Technical Review	CESWF-EC-DG	17	$ 89.00	$ 1,513
Review Comments:				
Preparation of Responses	CESWF-EC-DG	30	$ 53.00	$ 1,590
Review of responses	CESWF-EC-DG	5	$89.00	$ 445
Site Visits, Meetings, Etc.	CESWF-EC-DG	67	$ 53.00	$ 3,551
Total Geotechnical Engineering				***$ 27,268***

Cost Engineering and Specifications

During the plans and specifications phase of the project, the Independent Government Estimate will be prepared as a bid open estimate and will be based on quantity take-offs for all design items. The Specifications Section will prepare the front part of the project specifications, prepare the specifications for publication, accomplish any amendments, and prepare the official contract award CD after the bid opening.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Prepare IGE:				
Quality Control	CESWF-EC-AC	8	$ 77.00	$ 616
Bid Opening Package	CESWF-EC-AC	8	$ 70.00	$ 560
Civil Estimate	CESWF-EC-AC	48	$ 62.00	$ 2,976
HTRW Estimate	CESWF-EC-AC	24	$ 68.00	$ 1,632
Supervision & Administration	CESWF-EC-AC	4	$ 97.00	$ 388
Prepare Specifications:				
Quality Control	CESWF-EC-AC	16	$ 81.00	$ 1,296
Front Part of Specs	CESWF-EC-AC	40	$ 81.00	$ 3,240
Publication	CESWF-EC-AC	24	$ 79.00	$ 1,896
Amendments	CESWF-EC-AC	24	$ 79.00	$ 1,896
Award CD	CESWF-EC-AC	16	$ 79.00	$ 1,262
Supervision & Administration	CESWF-EC-AC	4	$ 97.00	$ 388
Total Cost Engineering and Specifications				***$ 16,152***

Hazardous, Toxic, and Radioactive Wastes Investigations (HTRW)

During the plans and specifications phase of the project, there will be no role for HTRW except to make the design team aware of the proximity of the former landfill at the FUDS site.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Meetings/Coordination	CESWF-PER-D	40	$ 63.00	$ 2,520
Total HTRW				***$ 2,520***

Environmental

During the plans and specifications phase of the project, a mitigation planting plan will be developed with the assistance of the landscape architect. Technical input on all plans to include the Hydraulic Channel Plan (which includes base flow channel, diversion channel, and diversion dikes) and the Mitigation Plan will be provided. Design drawings, construction contracts, and the Storm Water Pollution Prevention Plan will be reviewed. The Storm Water Notice of Intent will be filed. Project site visits and technical meetings will be attended.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Develop Mitigation Plan	CESWF-PER-EE	80	$ 65.00	$ 5,200
Review Design Drawings	CESWF-PER-EE	20	$ 65.00	$ 1,300
Review Contracts	CESWF-PER-EE	20	$ 65.00	$ 1,300
Provide Technical Input on All Plans	CESWF-PER-EE	40	$ 65.00	$ 2,600
Review Storm Water Pollution Prevention Plan	CESWF-PER-EE	10	$ 65.00	$ 650
File Storm Water Notice of Intent	CESWF-PER-EE	3	$ 65.00	$ 195
Site Visits; Meetings	CESWF-PER-EE	55	$ 65.00	$ 3,575
Total Environmental				***$ 14,820***

Cultural Resources

During the plans and specifications phase of the project, a systematic bank survey of the Willis Creek project area will be conducted. The trenching of specific locations and selective shovel testing will accompany the bank survey. The minimum requirement for the area from the Texas Historical Commission for trenching is 12 to 16 trenches (negotiable depending on identified previous disturbances and areas where there will be no project impacts). Approximately 50 to 80 shovel tests are likely in areas where deposits are shallow (reduceable if disturbances can be documented). An inventory of all buildings and structures within the project area or within any area of potential effect is required.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Bank Survey	CESWF-PER-EC	na	na	$ 7,500
Trenching/Shovel Tests	CESWF-PER-EC	na	na	$ 13,500
Backhoe/Gradall	CESWF-PER-EC	na	na	$ 18,000
Inventory Assessment	CESWF-PER-EC	na	na	$ 4,000
Analysis/Report	CESWF-PER-EC	na	na	$ 19,000
Additional Contractor Costs	CESWF-PER-EC	na	na	$ 4,000
FWD Contracting	CESWF-PER-EC	na	na	$ 3,000
Total Cultural Resources				***$ 69,000***

Real Estate

During the plans and specifications phase of the project, comments will be reviewed and made. Attendance at technical meetings will be a priority. Throughout the acquisition process, coordination with the City of Brownwood will be maintained.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Meetings	CESWF-RE	30	$ 73.00	$ 2,190
Comments	CESWF-RE	90	$ 73.00	$ 6,570
Coordination with City of Brownwood	CESWF-RE	90	$ 73.00	$ 6,570
Acquisition Review	CESWF-RE	479	$ 73.00	$ 34,967
Total Real Estate				***$ 50,297***

Operations and Maintenance

Following the construction of the project, an Operation and Maintenance Manual will be prepared.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Prepare O&M Manual	CESWF-OD-M	na	na	$ 4,000
Total Operations and Maintenance				***$ 4,000***

Plan Formulation Branch

During the plans and specifications phase of the project, Plan Formulation Branch will be involved throughout the entire lifespan of the phase to ensure continuity and provide planning reasoning and background. Design team meetings and public meetings will be attended. Various coordination efforts will be taken care of. Miscellaneous reports will be prepared.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Team Meetings	CESWF-PER-PF	na	na	$ 5,000
Coordination Efforts	CESWF-PER-PF	na	na	$ 5,000
Prepare Misc. Reports	CESWF-PER-PF	na	na	$ 5,000
Public Meetings/Travel	CESWF-PER-PF	na	na	$ 5,000
Reviews/Supervision	CESWF-PER-EC	na	na	$ 5,000
Total Plan Formulation				***$ 25,000***

Project Management

During the plans and specifications phase of the project, the project manager will continue to serve as the central point of contact with Headquarters, USACE; the sponsor; local partners; stakeholders; and other interested parties. The project manager will track and update the Project Management Plan as necessary. In addition, the project manager will monitor project schedules and finances, process schedule and cost changes, review budget documents, coordinate the PCA, and resolve problems and issues. The project manager will insure that all activities are proceeding as scheduled and that information is properly disseminated. The project manager will also coordinate with technical groups, maintain open dialogue with the sponsor, and respond to Congressional inquiries.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Management	CESWF-PM-C	na	na	$ 10,000
Monitor Schedule/Budget	CESWF-PM-C	na	na	$ 5,000
Negotiate PCA	CESWF-PM-C	na	na	$ 10,000
Prepare Budget Documents	CESWF-PM-C	na	na	$ 5,000
Local Coordination	CESWF-PM-C	na	na	$ 5,000
Public Meetings	CESWF-PM-C	na	na	$ 5,000
Total Project Management				***$ 40,000***

Design Branch

During the plans and specifications phase of the project, Design Branch will be involved throughout the entire lifespan of the phase to coordinate the project's design efforts. Design team, weekly, and public meetings will be attended. Financial management efforts (setting up labor accounts, allocating design funds, etc.) will be provided. Various reports and documents will be prepared. Final design drawings will be reproduced and sent out for review. The corrected drawings will be reproduced to be included in the package to be advertised.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Team/Weekly Meetings	CESWF-EC-D	60	$ 91.00	$ 5,460
Public Meetings/Travel	CESWF-EC-D	48	$ 91.00	$ 4,368
Coordination Efforts	CESWF-EC-D	150	$ 91.00	$ 13,650
Financial Management	CESWF-EC-D	72	$ 91.00	$ 6,552
Reproduction	CESWF-EC-D	na	na	$ 5,000
Supervision	CESWF-EC-D	40	$100.00	$ 4,000
Total Design Branch				***$ 39,030***

Contracts Support Section

During the plans and specifications phase of the project, the design drawings and the specifications will be reviewed and comments made. When the design package meets criteria, a BCOE Certificate will be issued.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Review Drawings and Issue BCOE Certificate	CESWF-EC-AS	16	$ 75.00	$ 1,200
Total Contracts Support Section				***$ 1,200***

Contracts Management Section

During the plans and specifications phase of the project, the design drawings and the specifications will be reviewed and comments made.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Review Design Drawings and Provide Comments	CESWF-EC-AM	24	$ 75.00	$ 1,800
Total Contracts Management Section				***$ 1,800***

Central Texas Area Office

During the plans and specifications phase of the project, the design drawings and the specifications will be reviewed and comments made.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Review Design Drawings and Provide Comments	CESWF-AO-C	na	na	$ 2,000
Total Central Texas Area Office				***$ 2,000***

Contracting

During the plans and specifications phase of the project, the bid package will be provided to prospective bidders. Submitted bids will be compared against the Independent Government Estimate and other criteria. A winning bidder will be selected and the contract awarded.

Major Task	Responsible Party	Man-Hours	Hourly-Rate	Total Cost
Provide Bid Package to Bidders & Award Contract	CESWF-CT	150	$50.00	$ 7,500
Total Contracting				***$ 7,500***

SUMMARY OF PLANS AND SPECIFICATIONS PHASE COST ESTIMATE

Tasks	Total Costs
Hydrology and Hydraulics	$ 28,704
Civil Engineering	$ 30,180
Utility, Road, and Bridge Relocations	$ 6.600
Structural Engineering	$ 28,050
Agronomy	$ 8,050
Geotechnical Engineering	$ 27,268
Cost Engineering and Specifications	$ 16,152
HTRW	$ 2,520
Environmental	$ 14,820
Cultural Resources	$ 69,000
Real Estate	$ 50,297
Operations and Maintenance	$ 4,000
Plan Formulation Branch	$ 25,000
Project Management	$ 40,000
Design Branch	$ 39,030
Contracts Support Section	$ 1,200
Contracts Management Section	$ 1,800
Central Texas Area Office	$ 2,000
Contracting	$ 7,500
Total Cost Estimate	***$ 402,171***

APPENDIX F

U.S. FISH AND WILDLIFE COORDINATION REPORT

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
WinSystems Center Building
711 Stadium Drive, Suite 252
Arlington, Texas 76011

October 3, 2001

Colonel Gordon M. Wells
District Engineer
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Colonel Wells:

This letter represents the report of the U.S. Fish and Wildlife Service (Service) on the Willis Creek Flood Damage Reduction Project within the City of Brownwood, Brown County, Texas. It is prepared under the authority of, and in accordance with, the Fish and Wildlife Coordination Act (FWCA) (48 Stat. 401, as amended; 16 U.S.C. 661 et.seq.) and is intended to accompany your Feasibility Report. Our report has been coordinated with the Texas Parks and Wildlife Department, as noted in the enclosed letter from Mr. Robert W. Spain, dated September 20, 2001.

In 1963, Brown County Water District No. 1 in cooperation with the City of Brownwood requested that the Fort Worth District Corps of Engineers (Corps) undertake a study on the feasibility of providing protection to residents and businesses experiencing damage from flood events within the Pecan Bayou watershed. This study was conducted under authority of the Pecan Bayou watershed plan authorized by the Flood Control Act of 1968 (Public Law 90-483) approved on August 13, 1968. The initially authorized Pecan Bayou watershed plan contained three units: Pecan Bayou Channel Improvement, Lake Brownwood Modification, and Pecan Bayou Reservoir. The Pecan Bayou Channel Improvement was subsequently de-authorized by House Document 97-59 in June 1981; the Lake Brownwood Modification was de-authorized on November 17, 1986 by the Water Resources Development Act of 1986 (PL 99-662).

In accordance with Federal regulations, Congressionally authorized (General Investigations) water resource studies, are performed in two phases; reconnaissance and feasibility. Based on the above authority, a reconnaissance study was completed in March 1994 to determine if there was a Federal interest in conducting additional detailed studies, the scope and cost of these additional studies, and to identify a non-Federal sponsor to participate. The report recommended additional detailed studies for flood damage reduction within the City of Brownwood. The Service provided planning assistance to accompany the Corps' reconnaissance report through a letter dated February 3, 1994. Our report identified and described existing fish and wildlife resources within the proposed project areas and

recommended preliminary measures for resource protection during early project planning.
The Corps initiated a cost-shared, feasibility study (shared equally between the Government and the City of Brownwood) in January 1995. In addition to the engineering aspects, environmental assessments were conducted during this time period to examine potential impacts of the project on natural resources. The Service initiated FWCA studies in cooperation with the Corps to evaluate the impact of the proposed flood damage reduction project on fish and wildlife resources and identify measures necessary for the protection, mitigation, or enhancement of these resources.

DESCRIPTION OF THE PROJECT AREA

Brown County is located on the western boundary of the Cross Timbers and Prairies Ecological Area of Texas. Total annual precipitation is approximately 27 inches, with an average temperature of 47 degrees Fahrenheit in winter and 83 degrees in the summer. The terrain varies from gently rolling hills to large expanses of gently sloping and flat areas. Geologically, the area lies within outcrops of Pennsylvanian, Permian, and lower Cretaceous strata which are primarily sedimentary in origin. Pecan Bayou is the major drainage through Brown County to the Colorado River.

The Pecan Bayou watershed is located in the north-central portion of the Colorado River Basin, near the geographical center of Texas. It is bounded on the north and east by the respective watersheds of the Clear Fork and Leon River tributaries of the Brazos River, and on the west and south by watersheds of small tributaries of the Colorado River. This pear-shaped watershed has an overall length of about 85 miles, a maximum width of about 40 miles, and an average width of about 26 miles. Major sub-watersheds include the North Prong, Hog Creek, Jim Ned Creek, Salt Creek, Willis Creek, Steppes Creek, Lewis Creek, Dudle Creek, Devils River, MacKinally Creek, Pecan Creek, Long Branch, Fish Creek, Rough Creek, and Blanket Creek. The total Pecan Bayou drainage area is approximately 2,200 square miles. Elevations within the Pecan Bayou watershed range from 2,370 feet (National Geodetic Vertical Datum) at the headwaters of Jim Ned Creek, to 1,150 feet at the confluence with the Colorado River. This is a total drop of 1,220 feet in 154 miles.

Soils along Pecan Bayou belong to the Frio-Sunev-Winter series which are characterized as nearly level to gently sloping, deep, loamy soils over loamy and clayey alluvium. These soils support an assemblage of large tree species such as pecan, oak, and elm which comprise the major component of the riparian woodlands along the length of the bayou. Generally, the vegetation type is classified as the Oak-Mesquite-Juniper Park/Woods complex with Ashe juniper, shin oak, Texas oak, blackjack oak, live oak, and cedar elm dominating the woodlands.

Land use above Lake Brownwood within the Pecan Bayou watershed is dispersed with several small homesteads and/or hunting and fishing camps located along the bayou. Ranches and small farms are generally located in the hilly uplands surrounding Pecan Bayou. Interspersed throughout the study area are old pastures and abandoned oil fields currently dominated by mesquite with an occasional oak stand and an understory of some or all of the following species: Texas pricklypear, purple three-awn, hairy grama, Texas grama, sideoats grama, curly mesquite, and Texas wintergrass. Cultivated cover crops or row crops, including oats, wheat, sorghum, peanuts, rye, barley, vetch, alfalfa, and millet are also located throughout the study area. Grassland, associated with crop rotation and/or cattle grazing, is another evident land use within the study area. Livestock production appears to consist mainly of cow-calf operations or growing sheep for the production of wool and lambs. Angora goats, swine, horses, and poultry are also raised throughout the county.

Hunting and fishing leases are a major enterprise in Brown County. Game species include white-tailed deer, Rio Grande turkey, northern bobwhite, ducks, geese, mourning dove, squirrels, and rabbits. Many of these species are closely associated with the habitat which occurs along Pecan Bayou and associated tributaries within the watershed. Grassland, cultivated crops, and old pastures also provide valuable habitat for endemic and migratory game and non-game wildlife species within the county.

Based on the problems and opportunities identified in the Corps' March 1994 Reconnaissance Report, flooding is a concern within the Pecan Bayou watershed, particularly along Pecan Bayou and Willis Creek in the City of Brownwood. The purpose of the Corps' ongoing feasibility study is to investigate opportunities to reduce flood damage along Willis Creek.

Willis Creek originates about five miles southwest of Brownwood and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The watershed has a drainage area of 28.4 square miles. The study area is defined as the Standard Project Flood Plain along Willis Creek beginning at its confluence with Pecan Bayou and extending upstream a distance of about 24,000 feet terminating near Asbury Street. Within the study area, Willis Creek is a gently, to moderately, meandering waterway having a top width ranging between 40 to 135 feet and depths between 4 and 11 feet. The slope is estimated to drop 2.92 feet per thousand foot of channel. Willis Creek has 3 concrete box culvert bridges, at Austin Street, 4th Street, and 14th Street. Located further upstream is a wooden railroad bridge and an arched rock culvert bridge at Crockett Drive. The majority of the study area is bordered on at least one side by residential development.

South Willis Creek is a principal tributary to Willis Creek. South Willis Creek originates a few miles due south of Brownwood and proceeds in a northerly direction to SCS floodwater retarding site "Brownwood Laterals #4A", at which point the total drainage area is 0.84 square miles. Below the damsite, it proceeds in a northerly direction to its confluence with Willis Creek. Another prominent feature of this watershed is SCS floodwater retarding site "Brownwood Laterals #4B", which is situated on the "Country Club" tributary. South Willis Creek has a drainage area of 10.7 square miles.

PLAN OF DEVELOPMENT

The National Economic Development (NED) plan identified during preliminary planning studies by the Corps for the Willis Creek local flood damage reduction project is a hydraulic channel modification. The modification begins near Asbury Street and extends approximately 6,400 feet downstream (about 1,200 feet downstream of 14th Street.) At this point, a diversion channel is excavated across an open field, reconnecting to Willis Creek about 2,000 feet downstream (approximately 500 feet upstream of 4th Street). From that point, the modified channel proceeds 7,880 feet to the downstream terminus of the plan. The modified channel, including the diversion channel has an average bottom width of 40 feet, with side slopes of 1 vertical on 3.5 horizontal. The plan requires modifications to two bridges. The four existing 8-foot by 6-foot culverts at 14th Street will be replaced with eight 10-foot by 10-foot culverts. Three 10-foot by 8-foot culverts will be added to the four existing 10-foot by 8-foot culverts on 4th Street. Riprap will be placed at the bridge approaches for erosion protection. Approximately 545 feet of different types of storm drain (reinforced concrete and galvanized pipe) will be extended. In addition, approximately 1,581 feet of various sanitary sewer, water, and gas utility lines will be relocated. The NED plan is displayed in Figure 1.

The estimated total and annual project cost is $5,952,700 and $446,400, respectively. The plan will reduce the expected annual flood damages of $956,600 by 88 percent or $844,200. The plan has a benefit-cost ratio of 2.0 and net benefits (annual benefits in excess of annual costs) of $433,400.

While the NED plan is initially identified as the Federally recommended plan, frequently the non-Federal partner will find it in their interest to pursue a plan that sacrifices some NED net benefit for additional contributions to other planning objectives. When the non-Federal partner prefers a plan that is not the NED plan, that plan is designated as the locally preferred plan (LPP). Preliminary coordination with the City of Brownwood indicates they will support the NED plan as the recommended plan.

EVALUATION METHODOLOGY

Wildlife evaluations were conducted for the Willis Creek Flood Damage Reduction project using the Service's Habitat Evaluation Procedures (HEP). This methodology permits the documentation of the quality and quantity of available habitat for selected wildlife species within a project area for both with-project and without-project conditions. It can be utilized to compare and/or predict available habitat under various development scenarios and time intervals, thus permitting the evaluation of development impacts on wildlife habitat and the formulation of appropriate mitigation measures.

HEP is based on the assumption that habitat for selected wildlife species can be described by a Habitat Suitability Index (HSI). This index value, which ranges from 0 (no suitable habitat) to 1.0 (optimal habitat conditions), is multiplied by the area of available habitat to obtain habitat units. The habitat units are normally annualized over the life-of-the-project in order to compare future habitat conditions under different alternatives. HSI's are obtained by comparing field measured habitat variables (e.g., tree canopy closure, number of nest sites, etc.) to optimum habitat criteria preferred by each wildlife evaluation species.

Within the Willis Creek Flood Damage Reduction project area, there were four major wildlife habitat cover-types identified and evaluated. These included riparian/bottomland hardwood forest, upland forest, shrubland/regeneration, and grassland/old field. Riparian/bottomland forests were characterized by mature, mast-producing species such as pecan, Texas oak, live oak, shin oak, post oak, red oak, hackberry, American elm, cedar elm, blueberry juniper with some gum bumelia, black willow, eastern cottonwood, Texas redbud, honey locust, mesquite, Texas mulberry, western soapberry, and chinaberry. Upland woodlands are dominated by stands of live oak, shin oak, Texas oak, post oak, American elm, cedar elm, hackberry, gum bumelia, hawthorn, blueberry juniper, mesquite, and western soapberry. Common species observed within the early successional, shrubland/regeneration cover type were mesquite, chinaberry, live oak, hackberry, cedar elm, honey locust, gum bumelia, hawthorn, and blueberry juniper. Principal herbaceous species within the grassland/old field cover type included Texas wintergrass, broomweed, baccharis, purple-leaf nightshade, moonseed, yucca, aster, goldenrod, dock, prickly pear, giant ragweed, johnsongrass, bermudagrass, mesquite, and blueberry juniper. Mapping and quantification of the acreage of these habitats was accomplished by the Corps' Environmental Resources Planning staff, with the assistance of the Service, utilizing low altitude aerial photographs, national wetland inventory maps, remote sensing data, Arcview, and ground verification.

Evaluation species for the HEP analysis were selected through the application of feeding and reproductive guild matrices. This process enabled the identification of key "indicator species" which represent the entire ecological community because of their varied feeding and reproductive requirements. Whenever possible, species selection was based upon available models of species that have high public interest, economic value, or restrictive ecological requirements.

Species selected for evaluation of the habitats in the Willis Creek Flood Damage Reduction project area included the raccoon, fox squirrel, barred owl, and Carolina chickadee for bottomland hardwood forests and upland woodlands; eastern cottontail, raccoon, red-tailed hawk, and scissortail flycatcher for shrubland/regeneration; and eastern cottontail, eastern meadowlark, and red-tailed hawk for the grassland/old field.

Baseline field data within the project area were initially collected during the fall of 1997. The HEP identified the average annual habitat units (AAHU's) which would occur for each habitat type within the overall project area for a 50-year period of analysis, both with and without the flood damage reduction project. A comparison of these AAHU values was used to quantify potential impacts the proposed project would have on wildlife habitats and permitted the Service to evaluate potential mitigation plans.

For the purpose of the HEP analysis, it was assumed that in the absence of a federal flood damage reduction project there would be no significant change (over the life of the project) in the amount of available terrestrial habitat within the project study area. The shrubland/regeneration habitat type would develop into early successional bottomland hardwoods, and habitat quality of the bottomland hardwoods and upland woodlands would continue to improve slightly due to natural successional processes. Implementation of the project would result in the immediate loss of habitat within the footprint of the channel improvements.

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

Aquatic Resources

Aquatic habitats investigated for this report include South Willis Creek and Willis Creek. South Willis Creek intersects Willis Creek upstream of Austin Avenue. Willis Creek flows northeast and merges with Pecan Bayou approximately three quarters of a mile west of FM 2126. Attempts were made to identify previous flood control measures on the watershed and to evaluate the existing value of the aquatic resources. According to the National Wetlands Inventory classification, Willis Creek and South Willis Creek are classified as riverine, lower perennial streams with an unconsolidated bottom and bank which is permanently flooded in some portions and seasonally flooded in others.

Basically, the character and composition of the aquatic resources of the Willis Creek watershed have been influenced by prior projects such as the channelization of portions of South Willis Creek and Willis Creek in 1943. Even though fishery resources have been altered through past "improvements" within the watershed, these channelized segments have regained some value for aquatic and semi-aquatic species. The riparian corridor does provide some shading from the cottonwood, willow, ash, and the occasional pecan trees which now line the creeks.

On Willis Creek upstream of the segment channelized in 1943, large trees such as pecan, oak, and elm form a dense riparian corridor. This provides shading to the creek, thus adding to the habitat value of this watershed. Flow in the creek is minimal during the summer months, having deep pools which retain suitable habitat for numerous fish species such as gar, carp, green sunfish, bass, and catfish. These larger pools play an integral part in the survival of many species during periods of low flows by providing a reliable water source and can also sustain fish year round. Enclosure 1 depicts some of the aquatic habitat features within the Willis Creek study area.

Terrestrial Resources

The Pecan Bayou watershed is situated in the West Cross-Timbers vegetational region. The region is characterized by rolling to hilly topography with moderate relief from relatively smooth plains to sharply eroded valleys. Surface drainage is rapid. Mesquite/oak woodlands and short to mid-height grasses occur on the slopes and hilltops, with denser stands of oak, elm, hackberry, ash, and pecan at the lower elevations and along local drainage features. Agricultural fields and pasture are intermingled with undeveloped land. Vegetation resources within the project area are also highly influenced by human activities and typically consist of four major cover types: riparian/ bottomland hardwoods, upland forest, shrubland/ regeneration, and grassland/ old field. Representative terrestrial cover-types are illustrated in Enclosure 2.

Pecan-oak-elm bottomland hardwoods occupy approximately 40 acres within the evaluation area and are characterized by a greater overall tree species diversity than what occurs in the upland woodlands. Dominant overstory on these bottomland sites includes pecan, Texas oak, live oak, shin oak, post oak, red oak, hackberry, American elm, cedar elm, with some black willow, eastern cottonwood, and honey locust.

The bottomland hardwood forest also has a varied understory consisting of tree saplings, shrubs, vines, and herbaceous plants. Typical understory species include blueberry juniper, gum bumelia, Texas redbud, mesquite, Texas mulberry, western soapberry, chinaberry, downy hawthorn, green hawthorn, privet, poison ivy, greenbriar, trumpet creeper, peppervine, Carolina moonseed, ironweed, tickclover, ragweed, honeysuckle, bluethorn lotebush, broomweed, bermudagrass, and inland seaoats.

Upland woodland habitat consists of an overstory of live oak, shin oak, Texas oak, post oak, American elm, cedar elm, and hackberry. This habitat also consisted of a very diverse, dense understory of gum bumelia, mesquite, dogwood, blueberry juniper, deciduous holly, western soapberry, bluethorn lotebush, greenbriar, Carolina moonseed, broomweed, prickly pear, sumpweed, giant ragweed, green hawthorn, downy hawthorn, elbow bush, honeysuckle, and mistletoe. Based on the information provided, there will be no impact to upland woodlands associated with the proposed project.

The shrubland/regeneration habitat consists primarily of abandoned agricultural fields which are reverting to a higher level of vegetative succession. Common species observed within the early successional, shrubland/regeneration cover type were mesquite, chinaberry, hackberry, cedar elm, honey locust, gum bumelia, green hawthorn, and blueberry juniper. Primary herbaceous species in this cover-type include common and coastal bermudagrass, johnson grass, greenbriar, giant ragweed, western ragweed, Carolina moonseed, Texas wintergrass, broomweed, threeawn, prickly pear, silverleaf nightshade, and wild grape. Based on the information provided, there will be no impact to shrubland/regeneration habitat associated with the proposed project.

The grassland/old field cover type occupies approximately 16 acres within the project study area. Some of these fields are still mowed and a few leased for hay production. Principal herbaceous species within the grassland/old field cover type include curley dock, aster, goldenrod, prickly pear, horsemint, purple-leaf nightshade, Indian blanket, black-eyed susan, Texas thistle, Mexican hat, giant ragweed, Texas wintergrass, broomweed, Carolina moonseed, yucca, johnsongrass, and common and coastal bermudagrass with a few scattered gum bumelia and mesquite trees.

Although in an area of urban development, the riparian corridor of Willis Creek still provides important habitat. The wildlife species present are generally limited to those tolerant of relatively high levels of human disturbance. These include mammals such as raccoon, opossum, fox squirrel, and small rodents; reptiles; amphibians; and numerous birds, ranging from the red-tailed hawk to various perching and songbirds such as chickadees, warblers, and sparrows. Several species of ducks have also been observed utilizing Willis Creek.

Endangered Species

The black-capped vireo (*Vireo atricapillus*) and the Concho water snake (*Nerodia harteri paucimaculata*) are federally listed endangered and threatened species, respectively, that may occur in Brown County. No black-capped vireo habitat is known to occur along the Willis Creek watershed. The Concho water snake occupies the Colorado-Concho River System in Central Texas and the Concho Water Snake Recovery Plan (Fish and Wildlife Service 1993) indicates "Concho water snake populations appear to be fairly continuous to about the Farm to Market 45 bridge upstream from the mouth of Pecan Bayou. However, "the Concho water snake has not been found in Pecan Bayou."

A survey was conducted by Service personnel to determine if the Concho water snake was present in the Pecan Bayou system in June of 1993. During the survey no Concho water snakes were identified; however, one blotched water snake and three diamondback water snakes were documented. Various literature and reports of previous Concho water snake investigations also were studied, and coordination was conducted with the Service's liaison to the Concho Water Snake Recovery Team. Based on these investigations, we have determined that no Concho water snakes are likely to occur along Pecan Bayou within the study area of this project. Therefore, this project is not likely to adversely affect the Concho water snake or it's habitat.

FISH AND WILDLIFE RESOURCES WITH THE PROJECT

Aquatic Resources

Willis Creek is mostly a perennial stream, except during periods of low rainfall or extended drought. The aquatic habitat within Willis Creek is abundant and diverse. The creek contains several riffle/run/pool complexes of various depths and gravel consistency, undercut banks, rock shelf outcrops, root wads, dead fall trees and branches. Although no formal fish population studies have been conducted in Willis Creek, numerous warmwater species of fish have been observed inhabiting the pool habitat of the stream.

Any form of channelization along Willis Creek would serve to degrade the existing aquatic resources of the watershed. Segments which have been previously impacted are of less concern than unaltered segments of the creek. Specifically, the parts of Willis Creek which have never been channelized are of greatest concern. Several non-structural alternatives to channelization were considered along the creek.

Several small, single-family homes have been built next to Willis Creek within the last 20 years, and a trailer park which is probably within the flood zone is located near South Willis Creek. The permanent evacuation of homes within the floodplain of Willis Creek was identified by the Corps as warranting further study as a result of preliminary screening. However, it was determined that this alternative was not economically feasible. In an attempt to determine if any portion of the above alternative was economically feasible, it was broken down by reach. Unfortunately, any attempt to identify a smaller number of structures for removal could not be completed based on the concept of "community cohesion". Basically stated, a permanent evacuation alternative could not be recommended which removes only a portion of the affected structures while leaving a number of structures within the same floodplain in the study area. Therefore, permanent evacuation was eliminated from further consideration.

The only other alternative identified as warranting further study was the hydraulic channel modification alternative. The objective of a hydraulic channel modification is to contain flood flows within the banks of the creek. Based on the results of the feasibility study, it became apparent that the alternative addressed the stated planning objectives and constraints, and met the technical, environmental, social and economic criteria.

Since it was determined that the hydraulic channel modification was the most effective and efficient alternative for reducing flood damages, the initial channel configuration needed to be refined to identify the one which maximizes net benefits, i.e., the National Economic Development (NED) plan. The NED plan was determined by varying bottom widths and altering the alignment to avoid known or potential ecological and cultural resources as well as other physical constraints such as contaminated material, bedrock, etc. The total length of Willis Creek in the study area is approximately 18,531 linear feet. The NED plan, as proposed, would adversely impact approximately 13,368 linear feet or 72% of the original stream.

Terrestrial Resources

Implementation of the Willis Creek Flood Damage Reduction alternative would have an unavoidable, negative impact on the terrestrial habitats and wildlife species within the project area. This would result from the direct impact of the alternative on floodplain habitats, especially bottomland hardwood forests and grassland/old fields. Table 1 represents the acreage of terrestrial habitats which would be impacted by the proposed Flood Damage Reduction project.

As can be observed from Table 1, the proposed alternative would impact a total of 47.66 acres of wildlife habitat within the overall study area. About 67%, or 31.73 acres, of this total habitat would be riparian corridor/bottomland hardwood forests associated with the floodplain of the Willis Creek watershed immediately upstream of its confluence with Pecan Bayou. Impacts to the grassland/old field cover-type would impact a total of 15.93 acres of wildlife habitat or about 33% of the total impacts of the project. This cover-type was originally in agricultural production and has either been abandoned or is still being mowed and used for hay production.

Table 1. Acreage of terrestrial habitat impacted by the proposed Willis Creek Flood Damage Reduction project.

HABITAT COVER-TYPE	**FLOOD DAMAGE REDUCTION**	**PERCENTAGE OF TOTAL IMPACTS**
Riparian/ Bottomland Hardwoods	31.73	67
Upland Woodlands	0	0
Shrubland/Regeneration	0	0
Grassland/ Old Field	15.93	33
TOTAL IMPACTS	47.66	100

The impact of the proposed project on the AAHU's provided by each cover-type is displayed in Table 2. This analysis confirms the above conclusion that the Willis Creek Flood Damage Reduction project would have a negative impact on all wildlife habitat types within the project area.

Table 2. Impact of the proposed project development plans on the AAHU's of terrestrial wildlife habitats.

HABITAT COVER TYPE	Baseline AAHU's	AAHU's With Project	Net Change in AAHU's
Riparian/Bottomland Hardwoods	24.26	0.16	- 24.10
Upland Woodlands	0	0	0
Shrubland/Regeneration	0	0	0
Grassland/Old Field	11.06	0.07	- 10.99

Endangered Species

Our data indicate that federally listed threatened, endangered, or proposed species, candidate species or designated critical habitat, would not be affected by the proposed Willis Creek Flood Damage Reduction project.

DISCUSSION

The Service has evaluated this project in accordance with the guidelines and directives contained in its Mitigation Policy (Federal Register 46[15]: 7644-7663, January 23, 1981). The Mitigation Policy provides guidance for Service biologists in the formulation of recommendations to avoid, reduce, or compensate project-related impacts to fish and wildlife resources. The extent of mitigation necessary to protect fish and wildlife resources is generally dictated by the value and scarcity of the resources of concern. This is facilitated by the placement of habitat/cover types or resources into one of four resource categories. These categories serve as a key element in setting appropriate planning goals for mitigating project-related habitat losses.

Riparian/bottomland hardwood forests within the project area provide a relatively high quality habitat for the evaluation species. HSI's for the bottomland hardwoods habitat ranged from 0.52 for fox squirrel to 0.90 for raccoon, averaging 0.74 for all evaluation species. The high values were generally a result of the diversity of the tree and shrub cover which included mast-producing species such as pecan and live oak as well as mature specimens of hackberry and American and cedar elm. Mature mast-producing trees provide food for the fox squirrel, raccoon, and many passerine birds. Large trees are important as nesting habitat for the fox squirrel and important escape cover for the raccoon and passerine birds. Smaller trees, especially pecan and oak species, are an important source of winter food for the fox squirrel and raccoon and provide nesting habitat and cover for resident and migratory passerine birds. Brush piles and snags located along the bank of the creek provide necessary food, cover, and shelter for the raccoon and passerine birds. One limiting factor that may have lowered the value of this habitat was the overall lack of significant stands of mature, hardmast producing trees.

Numerous federal, state, and private studies have documented the increased vulnerability and scarcity of bottomland hardwood forests in Texas and the rest of the United States. Statewide, over 63% of the bottomland hardwood forests have been lost to human activities such as forestry, agricultural, and water resource development practices. In addition, residential, commercial, and industrial developments in urbanized areas such as Brownwood, have resulted in increased adverse impacts to bottomland and riparian ecosystems due to encroachment on the floodplain and the need for flood control.

Based on the high value of the bottomland hardwoods to the evaluation species and their relative scarcity, we have classified them as a Resource Category 2 under the Mitigation Policy. Our mitigation planning goal for this resource category is "no net loss of inkind habitat value." Generally, this goal can be accomplished by avoiding negative impacts, restoring impacted areas, compensating for the impacts by creating or improving habitats at a different location, or through a combination of these measures.

The grassland/old field cover-type within the project area consists of above average quality habitat for the evaluation species. HSI's for the grassland/old field cover type ranged from a low of 0.40 for the red-tailed hawk to a high of 0.95 for the eastern cottontail, averaging 0.67 for all evaluation species. The grassland/old field cover-type provides open space and a seed source for passerine birds and the cottontail, as well as cover for escape and nesting in brush piles and along fence-rows. The only limiting factor for this cover-type was the lack of large trees for red-tailed hawks to perch and hunt. The grassland/old field cover-type is also relatively abundant in the project area as well as the region, state, and nation due to current land use practices and should be classified as Resource Category 3. Our mitigation planning goal for this resource category is "no net loss of habitat value while minimizing loss of inkind habitat value". Due to the quality of this habitat in the project area, we recommend it be restored inkind on or near the project area.

As noted in Table 2, implementation of the proposed project would result in the total loss of 24.10 AAHU's of bottomland hardwood forest and 10.99 AAHU's of grassland. Based on the resource category discussions above, these losses to bottomland hardwood and grassland habitats should be fully mitigated inkind. Since the channel will require future maintenance once the proposed project is completed, mitigation of hardwood and grassland habitat can only be accomplished through offsite improvement of existing forested areas, reforestation of grasslands, and restoration of native grasslands. Various alternative mitigation scenarios were developed and analyzed for their ability to mitigate hardwood and grassland losses under these constraints.

The alternative mitigation plans varied in acreage, habitat cover-type, and level of management in order to identify a plan which could fully compensate for the AAHU losses. Although only three mitigation plans are discussed in this report, numerous other alternatives could be identified and evaluated for their feasibility to mitigate habitat losses resulting from the proposed project. However, in developing other alternative mitigation plans it would be necessary to remember the mitigation planning goal of "inkind habitat replacement" for Resource Category 2 bottomland hardwoods and Resource Category 3 grasslands.

Table 3 displays three mitigation plans (Plans A-C) which were evaluated for their ability to mitigate bottomland hardwood and grassland habitat losses for the Willis Creek Flood Damage Reduction project. These mitigation plans were formulated by incrementally adding tracts of floodplain and adjacent uplands and analyzing increased AAHU's which could be realized with intensified wildlife management practices applied to the tracts.

A comparison of Tables 2 and 3 is needed to determine whether a specific mitigation plan would successfully compensate for project related impacts to bottomland hardwoods and grasslands. For example, Mitigation Plan A proposes to reforest 45 acres of grassland/ old field habitat with native bottomland hardwood species and restore another 16 acres of native grassland habitat to produce a total of 61 acres of mitigation lands. All 61 of these acres are currently considered grassland/old field habitat. Reforestation of the 45 acres of grassland/old field along with intensive management of the revegetated area and restoration of 16 acres of native grasslands would result in a gain of only 13.96 AAHU's for bottomland hardwoods and 10.99 AAHU's for grasslands. Although the gain of 10.99 would compensate for the loss of 10.99 AAHU's resulting from project-related impacts to grassland/old field habitat, the gain of 13.96 AAHU's in hardwood habitat value would not compensate for the loss of 24.10 AAHU's resulting from project-related impacts to bottomland hardwoods (Table 3). Therefore, additional mitigation lands would be required for bottomland hardwood management in order to increase the AAHU values and accomplish the inkind mitigation goal.

Table 3. Change in AAHU's for alternative mitigation plans at the Willis Creek Flood Damage Reduction project.

MITIGATION PLAN ALTERNATIVE	**A**	**B**	**C**
Riparian/Bottomland Hardwoods	+13.96	+20.17	+24.83
Grassland/Old Field	+10.99	+10.99	+10.99
Total Acres	61	81	96

A - 61 acres total; including 45 acres of bottomland hardwood reforestation and 16 acres of native grassland restoration.
B - 81 acres total; including 65 acres of bottomland hardwood reforestation and 16 acres of native grassland restoration.
C - 96 acres total; including 80 acres of bottomland hardwood reforestation and 16 acres of native grassland restoration.

Since full mitigation for the proposed project impacts was impossible to accomplish solely within mitigation plan A, additional options to offset these impacts were evaluated. Therefore, Mitigation Plan B includes the reforestation of an additional 20 acres of grassland/ old field habitat that when combined with the total 61 acres included in plan A would produce a total of 81 acres. Reforestation of the now 65 acres of grassland/old field along with intensive management of the revegetated area and restoration of 16 acres of native grasslands would result in a gain of only 20.17 AAHU's for bottomland hardwoods and 10.99 AAHU's for grasslands. Although closer, the gain of 20.17 AAHU's in hardwood habitat value would not compensate for the loss of 24.10 AAHU's resulting from project-related impacts (Table 3). Therefore, additional mitigation lands would be required for bottomland hardwood management in order to increase the AAHU values and accomplish the inkind mitigation goal.

In Mitigation Plan C, we incrementally added 15 acres of additional grassland/old field habitat to the current 81 acres and then evaluated the Plan's ability to compensate for project impacts. In HEP, it is often beneficial if the lowest quality cover types (i.e., grassland/old field) are used while determining which mitigation plan is appropriate for the proposed project because the highest gains in habitat are made by intensively managing the lowest quality habitat available. Therefore, in Mitigation Plan C an increase of approximately 24.83 AAHU's could be realized by intensively managing the 80 acres of grassland/old field so that it is converted into bottomland hardwoods (Table 3), thus offsetting the loss of 24.10 AAHU's resulting from the implementation of the proposed project (Table 2). As determined in plan A, the loss of 10.99 AAHU's of grassland/ old field habitat would be offset by intensively managing the remaining16 acres of mitigation land so that it is restored into native grasslands.

Assuming a high level of management, it was determined that a mitigation area of this size and vegetation composition would fully compensate for the losses of bottomland hardwoods and grasslands resulting from the proposed Flood Damage Reduction project. Management measures which would be required to improve habitat conditions within the mitigation lands include: selecting and establishing vegetation species based on their wildlife food and cover value that are native to the project area and would be able to survive seasonal flooding; protection of newly established woody vegetation from the damaging effects of beaver or nutria, if required; fencing all areas to control livestock or human disturbances, where necessary; and providing or enhancing escape, resting, and nesting cover by introducing nest boxes (for squirrels, passerine birds, and wood ducks), brush piles, stumps, logs, large boulders, or other similar habitat features.

In order to mitigate the adverse impacts of the proposed project, we recommend, as discussed above in Mitigation Plan C, the acquisition and management of approximately 96 acres of mitigation lands, consisting of grassland/old fields. This mitigation plan would adequately compensate for the losses of bottomland hardwood and grassland habitat values if appropriate management measures are implemented to increase habitat values on these lands. Therefore, we recommend that this plan be included as a feature of the Willis Creek Flood Damage Reduction project. Any approved mitigation plan should also include provisions for annual operation and maintenance funding to the managing entity, since habitat improvement and restoration will occur throughout the life-of-the-project. The final amount of mitigation lands and/or revegetation measures may be modified during final plan formulation provided the loss of 24.10 AAHU's of bottomland hardwoods and 10.99 AAHU's of grassland/ old field are fully realized.

Mitigation policy dictates that the mitigation lands be located contiguous to the project area if feasible. Therefore, the mitigation lands evaluated and included in our recommended plan consisted of grassland/old fields located either contiguous (within the Willis Creek watershed) to or in close proximity (within the Pecan Bayou watershed) to the project site. Lands which are required to mitigate unavoidable, adverse impacts of Flood Damage Reduction projects may be publicly or privately owned. However, in order to increase the habitat value of these lands it will be necessary to dedicate them in perpetuity for wildlife management and restrict public use to compatible activities. Compatible activities could include hunting, hiking/nature trails, or other similar low-density recreation opportunities. If mitigation lands remain in private ownership, they must receive long term protection through the establishment of deed restrictions or other protective agreements which would transfer with ownership of the property.

Reforestation of 80 acres of grassland/ old field habitat would require the planting of a large quantity of hardwood trees and shrubs. We recommend that a portion of the trees and shrubs be of a containerized size and mast producing. Larger trees are usually established more successfully and will provide wildlife values in a shorter time period than bareroot seedlings. Initial establishment of the plantings should utilize state-of-the-art techniques in order to maximize survival from drought and animal damage. Some available techniques include the use of growth hormones, slow release fertilizers, protective sleeves, adequate irrigation, weed control, and other similar measures.

A minimum of 100 hardwood trees and 50 shrubs per acre should be planted on the grassland sites in order to provide greater diversity and age class structure. Preferred tree species include various oaks (e.g., escarpment live oak, red oak, shin oak, post oak, Texas oak, and blackjack oak), pecan, netleaf hackberry, Texas mulberry, gum bumelia, cedar elm, and American elm. Trees such as cottonwood, mesquite, and black willow are not recommended for planting, since these plants readily invade managed sites, have lower wildlife food values, and usually need to be controlled in order to promote the growth of more valuable wildlife trees. Recommended shrubs include species such as Texas persimmon, green hawthorn, downy hawthorn, Reverchon hawthorn, Texas redbud, Carolina buckthorn, rough-leaf dogwood, western soapberry, and prairie flameleaf sumac. All planted trees and shrubs should be adequately maintained and have a survival rate of at least 80% after four growing seasons.

There would be a loss of grassland/old field habitat associated with the reforestation of bottomland hardwoods (Table 3). However, the loss of some grasslands is not a major concern, since the loss of this lower valued cover-type can be compensated by gains in higher resource category bottomland hardwoods in accordance with the Mitigation Policy.

Restoration of 16 acres of native grasslands would require the planting of a variety of native grass and forb species which have proven food and cover values. Examples of preferred grass species include big and little bluestem, switchgrass, Indiangrass, sideoats grama, reed canarygrass, eastern gamagrass, and various panicums. Some native forbs which provide high wildlife habitat values include the partridgepeas, crotons, Illinois bundleflower, sunflowers, coneflowers, purple prairieclover, tickclover, Engelmann daisy, eryngos, lupines, wildbeans, and native wildflower mixes.

In addition to the reforestation of native bottomland hardwoods and restoration of native grasslands, mowing or other intensive maintenance activities should be restricted to the season of the year most compatible with wildlife reproduction, primarily late fall and winter. This would permit vegetation to go to seed, thus providing greater vegetative production. It would also provide greater cover and food values during the spring of the year, when wildlife reproduction and survival are most dependant upon adequate cover and the higher food values provided by lush vegetation (i.e., green vegetative material, seeds, and insects). Where feasible, mowing of the project area should be restricted to invasive, woody vegetation and not scheduled on a regular basis. No mowing should occur on any of the forested, wildlife mitigation lands once permanent vegetation is reestablished. In order to protect lands acquired for wildlife mitigation purposes, fencing should be provided to control livestock and human encroachment.

Finally, significant impacts to aquatic habitats and water quality would occur as a result of the realignment of approximately 13,368 linear feet of Willis Creek. Portions of the project are proposed to occur in previously channelized areas, therefore, removing vegetation and degrading habitat that has reestablished in the last 58 years. Furthermore, channelization of previously unaltered segments of Willis Creek would also destroy existing higher quality habitat. Additionally, the construction would adversely modify and fragment terrestrial habitat along the creeks to the extent that it would lose much if its value to wildlife. This would serve to reduce overall wildlife species utilization and diversity in these areas. Therefore, every effort should be made to avoid or preserve valuable aquatic habitat concurrent with achieving the flood damage reduction objectives during the design phase of this project.

Based on information from the NED plan, impacts to the highest quality segments of Willis Creek and its associated riparian corridor were avoided by using "high flow" swales designed to carry flood flows directly across the land area contained inside a bend. In these creek bends, base water flow would be maintained during normal flow periods for the preservation of the natural stream channel. Additional mitigation for impacted aquatic habitat would be to construct an earthen base flow channel approximately 15 feet wide x 2.5 feet deep that mimics the streams' original sinuosity, and place ten low-water retention structures at base grade along the stream to create pool habitat. Native aquatic macrophytes will also be planted in the base flow channel to provide additional habitat for fish and wildlife.

RECOMMENDATIONS

In order to avoid and reduce project-related impacts from the proposed Willis Creek Flood Damage Reduction project on fish and wildlife resources, the Service recommends the following:

1. Mitigation lands consisting of at least 96 acres comprised of grassland/old field cover-type be acquired and specifically dedicated for wildlife management activities. The grasslands evaluated and included in the recommended mitigation plan must be contiguous (within the Willis Creek watershed) to or in close proximity (within the Pecan Bayou watershed) to the project area. If necessary, authorization for the acquisition of these mitigation lands be sought from Congress as an integral component of the Willis Creek Flood Damage Reduction project.

2. The mitigation lands be managed to optimize wildlife habitat values through the reforestation of 80 acres floodplain grasslands and the restoration of native grasslands on the remaining 16 acres. Bottomland hardwood reforestation sites should be planted with a minimum of 100 native

hardwood trees and 50 shrubs per acre, while restored grassland sites should be planted with a mix of native grasses and forbs. A minimum survival rate of 80% after four growing seasons would need to be attained for hardwood plantings.

3. Public recreation use of the wildlife mitigation areas be restricted to compatible, low-density activities such as hunting, hiking/nature trails, wildlife observation, or other similar low impact recreation opportunities.

4. Operation and maintenance funding be provided annually in the project budget for management of the proposed fish and wildlife features on the mitigation lands.

5. Mowing and other intensive maintenance activities on project lands be restricted, whenever possible, to the late fall and winter months in order to provide optimum wildlife food and cover during the spring and summer reproductive season. Mowing should be restricted to the removal of invasive, woody species and not scheduled on a regular basis. No mowing should occur on the designated wildlife mitigation lands following successful reestablishment of woody vegetation.

6. Fencing should be constructed on all property included for the mitigation of project impacts in order to control livestock and human disturbances.

7. Impacted aquatic habitat be compensated for by constructing an earthen base flow channel approximately 15 feet wide x 2.5 feet deep that mimics the streams' original sinuosity. Ten low-water retention structures should be constructed at base grade along the stream to create pool habitat. Native aquatic macrophytes should also be planted in the base flow channel to provide additional habitat for fish and wildlife.

8. The Corps of Engineers and project sponsor consult with the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department during the development of detailed project plans and specifications in order to ensure full consideration of fish and wildlife mitigation features as a project component.

We appreciate the opportunity to provide our analysis and recommendations for fish and wildlife conservation during the planning of the Willis Creek Flood Damage Reduction project. Our report is based on the information provided prior to September 2001, and is subject to revision should the Corps modify project plans or evaluate other alternatives at some point in the future. For additional technical assistance or questions regarding implementation of our recommendations, please contact Mike Armstrong of my staff at the letterhead address or telephone (817) 277-1100.

Sincerely,

Tom Cloud

Thomas J. Cloud, Jr.
Field Supervisor

enclosures

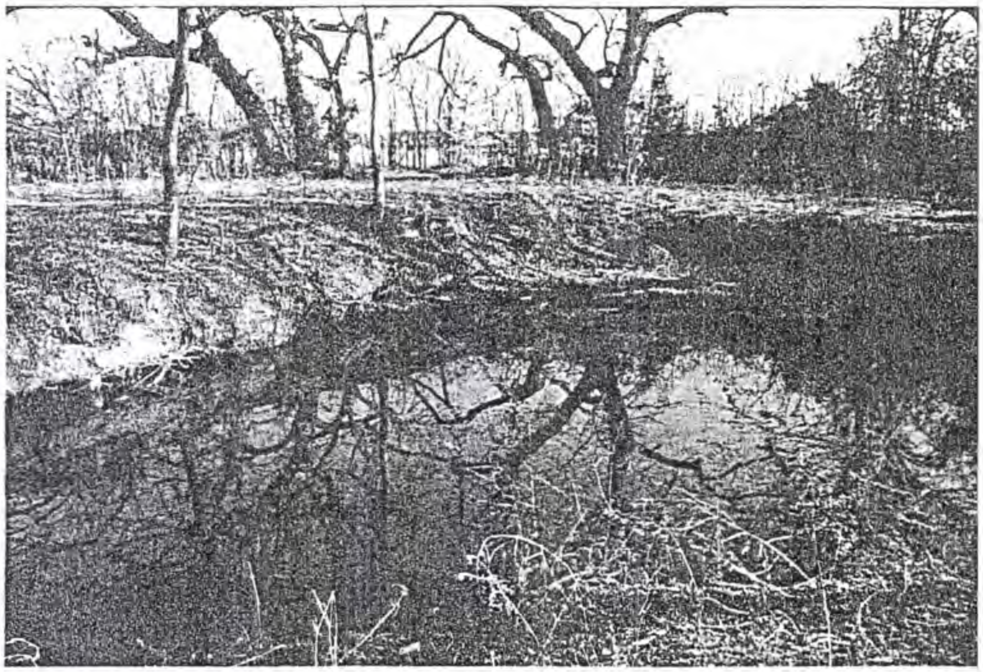
cc: Executive Director, TPWD, Austin, Texas (Resource Protection Division)
Complex Supervisor, FWS, Austin, Texas

ENCLOSURE 1

Representative aquatic habitats within the Willis Creek Watershed

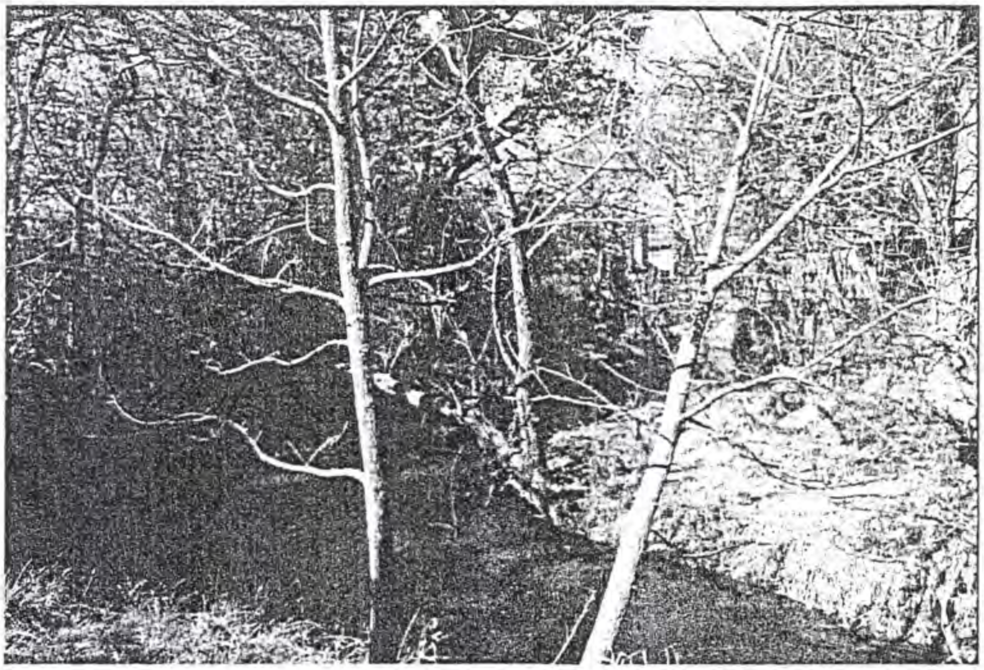
Previously channelized portion of Willis Creek

Riffle habitat

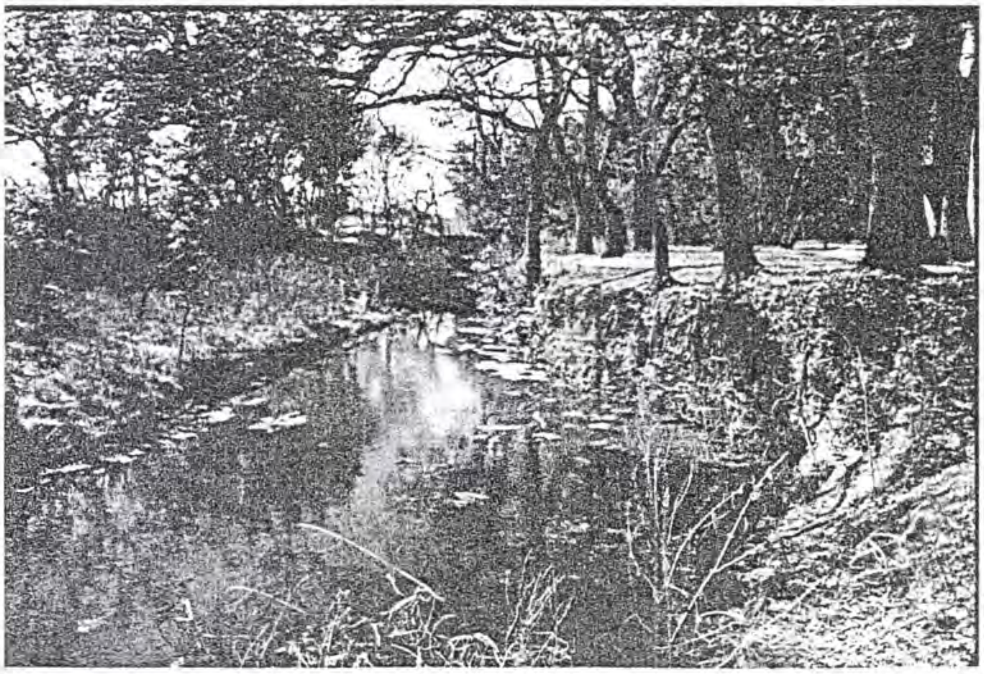


Pool habitat

In-channel dam



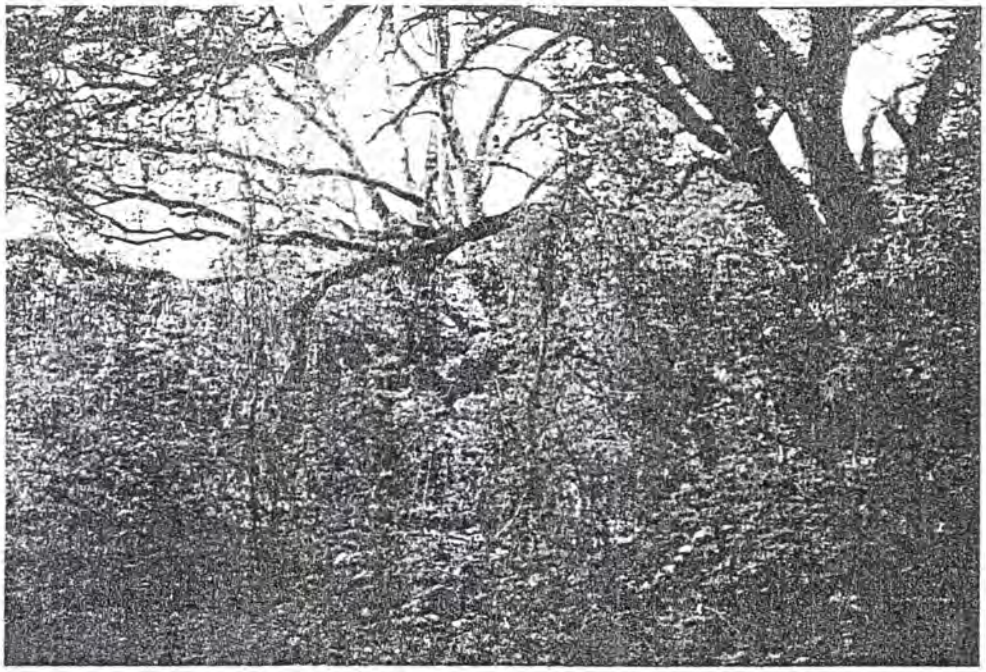
Sharp bend in Willis Creek



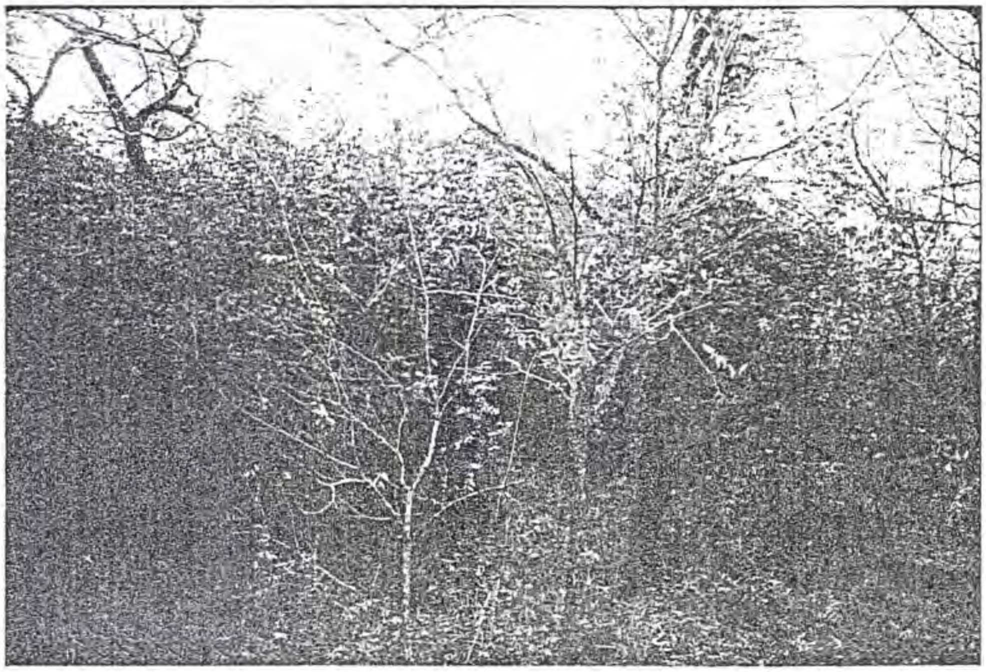
Streambank erosion and sedimentation

ENCLOSURE 2

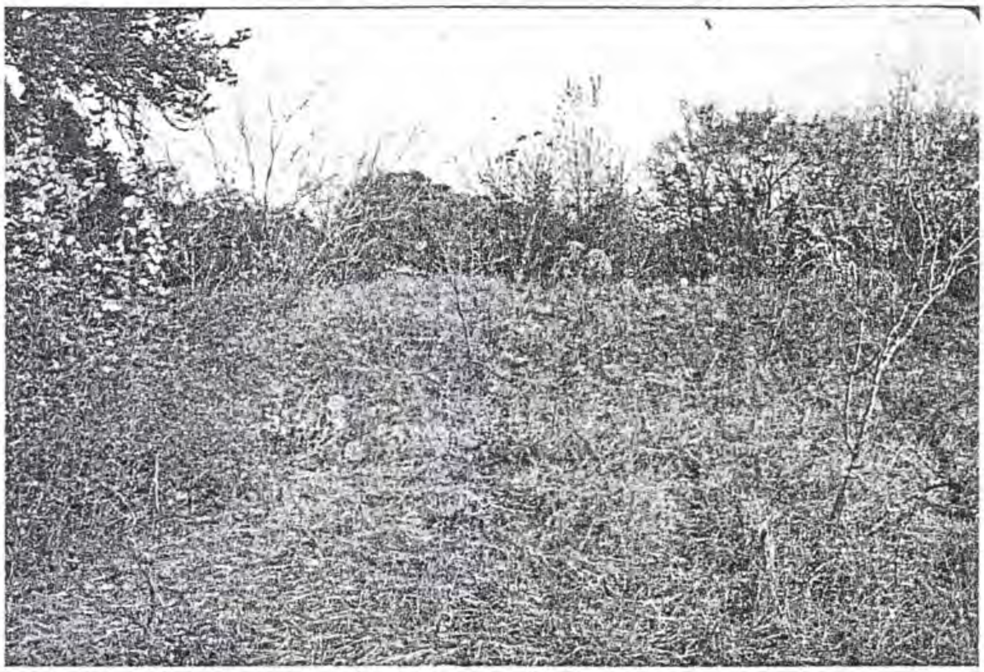
Representative Terrestrial Cover-types within the Willis Creek Watershed



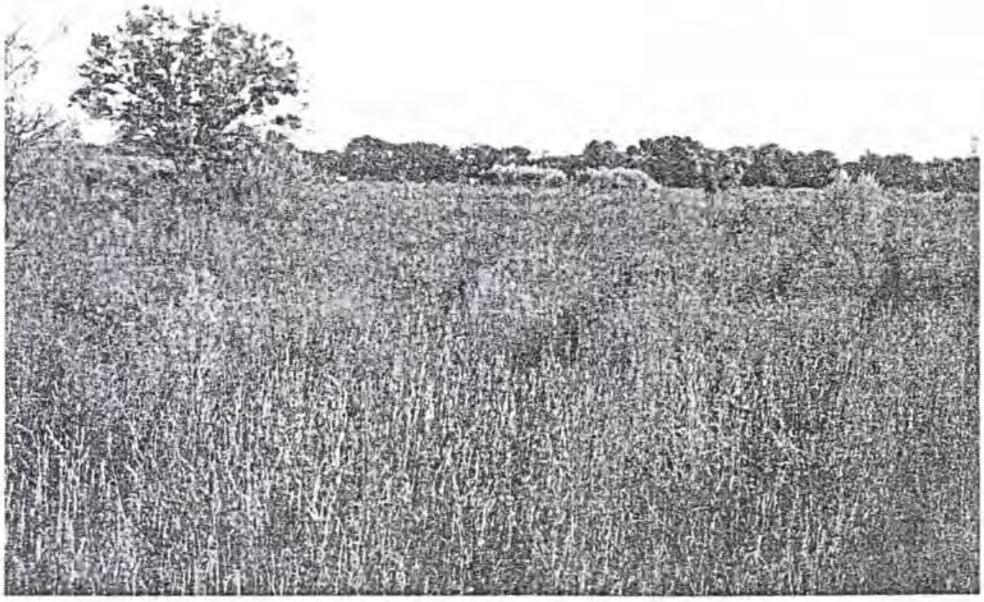
Riparian/ Bottomland hardwoods



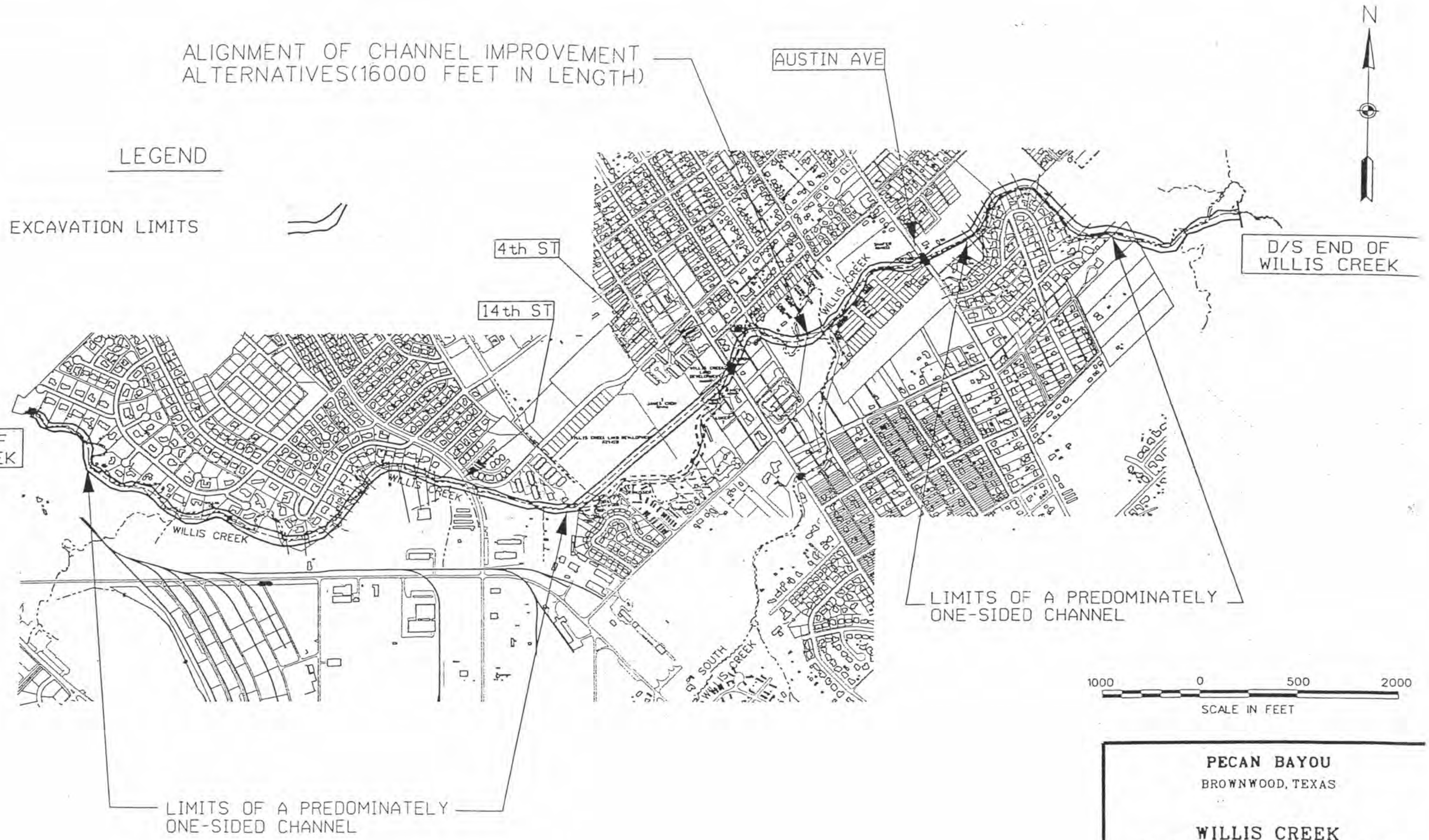
Upland woodlands



Shrubland/ Regeneration habitat



Grassland



PECAN BAYOU
BROWNWOOD, TEXAS

WILLIS CREEK
CHANNEL IMPROVEMENT

FIGURE 1.

FW-ES /	
FS	9/21
AFS	/
ALL	
MA	MA
OAST	
FILE	
NO.	
DUE	

TEXAS
PARKS &
WILDLIFE

September 20, 2001

Fort Worth District
Project Management Division
P.O. Box 17300
Fort Worth, Texas 76102-0300

Mr. Mike Armstrong
Winsystems Center Building
U.S. Fish & Wildlife Service
711 Stadium Dr., Suite 252
Arlington, Texas 76011

Reference: Pecan Bayou Watershed Draft Interim Feasibility Report and Integrated Environmental Assessment

The Fort Worth District of the U.S. Army Corps of Engineers proposes the construction of a flood damage reduction project within the city limits of Brownwood, Texas. This project would consist of the channelization of Willis Creek, resulting in a 15,680-foot-long grass-lined channel. This channel would have side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with a pilot channel. The proposed channel depth would vary from 4 to 11 feet with the top width varying between 40 to 135 feet. Alternating bank sloping is proposed to be utilized, which would result in the removal of vegetation and modification of alternating sides of Willis Creek.

The environmental assessment describes Willis Creek as having large oak, pecan, willow, hackberry, and elm trees along the riparian corridor that shade the creek and provide important wildlife habitat. Willis Creek experiences seasonal high and low flows, and has many large pools along the watercourse that can sustain fish populations throughout the year.

The initial screening of possible structural and nonstructural alternatives identified permanent evacuation and hydraulic channel modification as two considered alternatives that warranted further study. The nonstructural plan was eliminated from consideration because it was determined not to be economically feasible in complying with the planning objectives. Due to the elimination of the nonstructural alternative, only the hydraulic channel modification alternative was fully analyzed in the Environmental Assessment.

TPW staff recommends that the permanent evacuation alternative be reconsidered and analyzed more fully, as a nonstructural alternative would be the least damaging alternative to existing natural resources. As mentioned in an email to Mike Armstrong of the Fish & Wildlife Service on August 28, 2001, the buyout and removal of structures in the 50-year (2% ACE) or even 25-year (4% ACE) floodplain would result in flood-related damages occurring

4200 SMITH SCHOOL ROAD
AUSTIN, TEXAS 78744-3291
512-389-4800
www.tpwd.state.tx.us

much less frequently while also preserving valuable stream habitat. A smaller-scale project may then be capable of protecting the remaining structures in the floodway. Perhaps the buyout endeavor would be more economically feasible if the creation of a greenbelt or city park along Willis were considered. If a greenbelt that preserves the existing riparian habitat were created, residential properties adjacent to the greenbelt would increase in value, helping to offset the cost of structure buyout and removal from the floodplain.

Channelization of a stream results in not only the loss of valuable riparian and stream habitats, but also in altered hydrologic conditions downstream of the channel modification. This frequently causes increased erosion and sedimentation within the channelized reach and downstream. The principles of fluvial geomorphology should be applied to both create an appropriately functioning channel design, and to provide for the habitat that, in fact, stabilizes the channel. In comparing alternatives, all costs of mitigation as well as maintaining and repairing the altered channel should be included.

Although many measures are proposed to minimize impacts to the channel of Willis Creek, the stream channel itself will be irrevocably altered by the proposed channelization project. These impacts can be avoided by the selection of a non-structural alternative, which would preclude the necessity to mitigate for riparian corridor and stream habitat. The mitigation plan provides for the restoration of a bottomland area to mitigate for the riparian habitat that would be impacted, and proposes a section of Willis Creek to be preserved to mitigate for impacts to the stream itself. TPW staff understands that measures would be taken to ensure that the preserved section of Willis Creek would receive some flow at times during the year. However, the section would not function as part of a contiguous stream as it does now. Because impacts to stream channels are so difficult to mitigate, TPW staff recommends that options other than channelization be examined more closely.

Questions can be directed to Jennifer Key in Austin (512-389-8521), or to Tom Heger (512-389-4592).

Sincerely,

Bob Spain

Robert W. (Bob) Spain
Assistant Director, Resource Protection Division

RWS:JSK:JRM:msf

APPENDIX G

OTHER CORRESPONDENCES

City of Brownwood

December 18, 2001

Col. Gordon Wells
Department of the Army
Fort Worth District
Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

RE : Willis Creek Channelization Project

Dear Col. Wells:

The Brownwood City Council, with action taken at its November 13, 2001 Council meeting, is requesting the Corps of Engineers begin the Plans and Specifications phase of the outlined project.

It is our intent to formalize a broad range project that will include a comprehensive drainage study in addition to the channel project.

We appreciate the Corps of Engineers for your work on our flooding issues and we look forward to this next phase of the project.

Sincerely,

Gary Butts
City Manager

GB:lb

cc: Tom Vogt

POST OFFICE BOX 1389 • PHONE 915 646-5775 FAX 915 646-0938 • BROWNWOOD, TEXAS 76804

City of
Brownwood

April 19, 2002

Mr. Tom Vogt, P.E.
Project Manager
Dept. of the Army
Fort Worth District
Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

Re : Willis Creek Channelization Project

Dear Mr. Vogt:

For the above referenced project, the City of Brownwood's portion would be funded through the issuance of General Obligation Bonds, after having been approved by a vote of the public.

Maintenance and Operation costs would be covered through the City's annual budget. If you require additional information, please advise.

Sincerely,

Gary Butts

Gary Butts
City Manager

GB:lb

BROWNWOOD TX
FEELS LIKE HOME
POST OFFICE BOX 1389
BROWNWOOD, TEXAS 76804
PHONE 915-646-5775
FAX 915-646-0938

Robert J. Huston, *Chairman*
R. B. "Ralph" Marquez, *Commissioner*
Kathleen Hartnett White, *Commissioner*
Jeffrey A. Saitas, *Executive Director*

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

March 28, 2002

Mr. Paul M. Hathorn
U.S. Army Corps of Engineers
Regulatory Branch CESWF-EV-R
P.O. Box 17300
Fort Worth, Texas 76102-0300

RE: USACE Willis Creek Channel Improvement, Brownwood, Texas

Dear Mr. Hathorn:

The U.S. Army Corps of Engineers (Corps) is seeking 401 certification on a channel modification of Willis Creek. The proposed plan will perform 15,680 feet of channel modifications along a stretch of Willis Creek within the city of Brownwood, in Brown County, Texas. Alternating bank sloping has been proposed to reduce the environmental impacts of the project. Several bends of the original creek bottom will be bypassed during flood conditions, but base flow will be maintained in these areas with low water retention structures. Also, the thalweg of the original stream corridor will be mimicked in the new channel to offset some of the impacts to aquatic resources. In addition to the measures used to minimize the impacts of the channel modifications, the Corps will restore an 1,800 linear foot segment of South Willis Creek in Festival Park as compensatory mitigation for unavoidable impacts to aquatic resources due to the project.

In response to the Joint Public Notice dated August, 03, 2001, and the revised Interim Feasibility Report dated March 2002, the Texas Natural Resource Conservation Commission (TNRCC) certifies that the activity should not result in a violation of established Texas Water Quality Standards as required by Section 401 of the Federal Clean Water Act and pursuant to Title 30, Texas Administrative Code, Chapter 279, provided that the standard provisions in Attachment 1 are followed.

Wetlands are protected by the Texas Water Quality Standards, and they play a major role in maintaining water quality standards. The TNRCC supports a goal of no net loss of wetlands.

No review of property rights, location of property lines, nor the distinction between public and private ownership has been made, and this certification may not be used in any way with regard to questions of ownership.

P.O. Box 13087 • Austin, Texas 78711-3087 • 512/239-1000 • Internet address: www.tnrcc.state.tx.us

If you require additional information or further assistance, please contact Mr. Robert Burgess, Water Quality Assessment Section, Water Quality Division (MC-150), at (512) 239-3163, or by e-mail at *rburgess@tnrcc.state.tx.us*.

Sincerely,

FOR

Jeffrey A. Saitas, P.E., Executive Director
Texas Natural Resource Conservation Commission

DL/RB/mh

Attachment No. 1

Attachment 1 - Dredge and Fill Certification
USACE Willis Creek Channel Improvement, Brownwood, Texas
March 28, 2002

WORK DESCRIPTION: As described in the public notice dated August 03, 2001 and Interim Feasibility Report dated March 2002.

SPECIAL CONDITIONS: None

GENERAL: **This certification, issued pursuant to the requirements of Title 30, Texas Administrative Code, Chapter 279, is restricted to the work described in the application or joint public notice and shall expire five years from the date of issuance.** This certification may be extended to any minor revision when such change(s) would not result in an impact on water quality. The TNRCC reserves the right to require full joint public notice on a request for minor revision. The applicant is hereby placed on notice that any activity conducted which results in a violation of the state's surface water quality standards may result in an enforcement proceeding being initiated by the TNRCC or a successor agency.

STANDARD PROVISIONS: These following provisions shall be followed by the Corps or any employee, agent, contractor, or subcontractor of the Corps during any phase of work authorized.

1. The water quality of wetlands shall be maintained in accordance with all applicable provisions of the Texas Surface Water Quality Standards including the General, Narrative, and Numerical Criteria.

2. The applicant shall not engage in any activity which will cause surface waters to be toxic to man, aquatic life, or terrestrial life.

3. Corps shall employ measures to control spills of fuels, lubricants, or any other materials to prevent them from entering a watercourse. All spills shall be promptly reported to the TNRCC, Emergency Spill Response, at (512) 463-7727.

4. Sanitary wastes shall be retained for disposal in some legal manner. Marinas and similar operations which harbor boats equipped with marine sanitation devices shall provide state/federal permitted treatment facilities or pump out facilities for ultimate transfer to a permitted treatment facility. Additionally, marinas shall display signs in appropriate locations advising boat owners that the discharge of sewage from a marine sanitation device to waters in the state is a violation of state and federal law.

5. Materials resulting from the destruction of existing structures shall be removed from the water or areas adjacent to the water and disposed of in some legal manner.

6. A discharge shall not cause substantial and persistent changes from ambient conditions of turbidity or color. The use of silt screens or other appropriate methods is encouraged to confine suspended particulates.

7. The placement of any material in a watercourse or wetlands shall be avoided and placed there only with the approval of the Corps when no other reasonable alternative is available. If work within a wetland is unavoidable, gouging or rutting of the substrate is prohibited. Heavy equipment shall be placed on mats to protect the substrate from gouging and rutting if necessary.

8. Dredged Material Placement: Dredged sediments shall be placed in such a manner as to prevent any sediment runoff onto any adjacent property not owned by the applicant. Liquid runoff from the disposal area shall be retained on-site or shall be filtered and returned to the watercourse from which the dredged materials were removed. Except for material placement authorized by this permit, sediments from the project shall be placed in such a manner as to prevent any sediment runoff into waters in the state, including wetlands.

9. If contaminated spoil that was not anticipated is encountered during dredging, dredging operations shall be immediately terminated and the TNRCC, Emergency Spill Response, shall be contacted at (512) 463-7727. Dredging activities shall not be resumed until authorized by the Commission.

10. Contaminated water, soil, or any other material shall not be allowed to enter a watercourse. Noncontaminated stormwater from impervious surfaces shall be controlled to prevent the washing of debris into the waterway.

11. Stormwater runoff from construction activities (US EPA Category X) is governed by the requirements of the US Environmental Protection Agency. Applications to apply for a general permit are to be obtained from Region 6, US EPA at (214) 665-7185.

12. Upon completion of earthwork operations, all temporary fills shall be removed from the watercourse/wetland, and areas disturbed during construction shall be seeded, riprapped, or given some other type of protection to minimize subsequent soil erosion. Any fill material shall be clean and of such composition that it will not adversely affect the biological, chemical, or physical properties of the receiving waters.

13. Disturbance to vegetation will be limited to only what is absolutely necessary. After construction, all disturbed areas will be revegetated to approximate the pre-disturbance native plant assemblage.

14. Where the control of weeds, insects, and other undesirable species is deemed necessary by the Corps, control methods which are nontoxic to aquatic life or human health shall be employed when the activity is located in or in close proximity to water, including wetlands.

15. Concentrations of taste and odor producing substances shall not interfere with the production of potable water by reasonable water treatment methods, impart unpalatable flavor to food fish including shellfish, result in offensive odors arising from the water, or otherwise interfere with reasonable use of the water in the state.

16. Surface water shall be essentially free of floating debris and suspended solids that are conducive to producing adverse responses in aquatic organisms, putrescible sludge deposits, or sediment layers which adversely affect benthic biota or any lawful uses.

17. Surface waters shall be essentially free of settleable solids conducive to changes in flow characteristics of stream channels or the untimely filling of reservoirs, lakes, and bays.

18. The work of the applicant shall be conducted such that surface waters are maintained in an aesthetically attractive condition and foaming or frothing of a persistent nature is avoided. Surface waters shall be

maintained so that oil, grease, or related residue will not produce a visible film of oil or globules of grease on the surface or coat the banks or bottoms of the watercourse.

19. This certification shall not be deemed as fulfilling the Corps's responsibility to obtain additional authorization/approval from other local, state, or federal regulatory agencies having special/specific authority to preserve and/or protect resources within the area where the work will occur.

PEL-B

TEXAS
HISTORICAL
COMMISSION

The State Agency for Historic Preservation

RICK PERRY, GOVERNOR
JOHN L. NAU, III, CHAIRMAN
F. LAWERENCE OAKS, EXECUTIVE DIRECTOR

April 11, 2002

William Fickel, Jr.
Chief, Environmental Division
CESWF-EV-EC
Dept. of the Army
Ft. Worth District, Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Re: Review under Section 106 of the National Historic Preservation Act
Revised Draft Interim Feasibility Report and Environmental Assessment
Pecan Bayou Watershed, Brownwood Texas (COE-FWD)

Dear Mr. Fickel:

Thank you for allowing us to review the revised draft document referenced above. This letter serves as comment on the document from the State Historic Preservation Officer, the Executive Director of the Texas Historical Commission.

The review staff, led by Bill Martin, has completed its review. We concur that an intensive survey for archeological sites and historic structures and buildings should be conducted during the Plans and Specifications phase. We wish to review the scope-of-work proposed for this survey before it is sent out for bids. Please forward a copy of the draft scope-of-work when it is developed.

Thank you for your cooperation in this federal review process, and for your efforts to preserve the irreplaceable heritage of Texas. **If we may be of further assistance, please contact Bill Martin at 512/463-5867.**

Sincerely,

William A. Martin
for
F. Lawerence Oaks, State Historic Preservation Officer

FLO/wam

P.O. BOX 12276 · AUSTIN, TX 78711-2276 · 512/463-6100 · FAX 512/475-4872 · TDD 1-800/735-2989

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF:

August 03, 2001

Planning, Environmental, and Regulatory Division

Mr. Mark Fisher
Research and Environmental Assessment Section
Water Planning and Assessment Division
Texas Natural Resource Conservation Commission MC 150
12100 Park Circle 35, Building F
P.O. Box 13087, Capitol Station
Austin, TX 78711

Dear Mr. Fisher:

The Fort Worth District in conjunction with the City of Brownwood, Texas, proposes construction of a local flood damage reduction project of Willis Creek within the city limits of Brownwood, Texas. The USACE, Fort Worth District has conducted an environmental assessment (EA) and prepared a draft Finding of No Significant Impacts (FONSI) for construction of the proposed plan. **As indicated in the attached NOA, the public is being concurrently notified of the opportunity to provide comments to the TNRCC regarding the certification by your office of the proposed project and its compliance with state water quality standards.**

The alternative preferred by the city, designated the "recommended" alternative, and one other alternative was evaluated for the proposed action. The preferred action by the city would be to construct a channel modification consisting of 15,680 feet of hydraulic channel modification on Willis Creek within the city of Brownwood. The recommended plan consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. Approximately 96 acres of reforestation would be undertaken to mitigate habitat removed by the channel modification. The non-structural alternative of floodplain evacuation was also examined; however, the alternative was not feasible due to disruption of community cohesion and lack of sponsorship. The channel modification of Willis Creek was identified as the NED plan.

Construction of the recommended plan would adversely impact approximately 13,336 linear feet of jurisdictional waters of the United States. In the draft Fish and Wildlife Coordination Act Report, dated 23 May 2001, the U.S. Fish and Wildlife Service recognized that the Willis Creek Flood Damage Reduction Project would adversely impact high quality terrestrial and aquatic resources. For adverse impacts to terrestrial resources, the U.S. Fish and Wildlife Service recommended the acquisition and management of approximately 96 acres of mitigation lands consisting of grassland/old fields and bottomland hardwoods contiguous to the project area.

The mitigation plan for adverse impacts to the terrestrial resources of Willis Creek resulting from the recommended channel modification would consist of converting 80 acres of grassland/old field to bottomland hardwood habitat and restoring 16 acres of native grasslands. The mitigation areas would be located at the Brownwood Municipal Airport and Riverside Park North (Craven's Estate). Planting a minimum of 100 hardwood, mast-producing trees and 50 fruit-bearing shrubs per acre, would be planted for conversion of grassland/old field habitat. Restoration of the native grasslands would require the planting of a variety of native grass and forb species that are native to Texas and have proven wildlife food and cover value. Planting a mixture of native grasses and forbs to stabilize soils on newly constructed channel side slopes would also be performed. Several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for wildlife. Construction of a base flow or low-flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity, the placement of ten, low-water retention structures at base grade along the stream to create pool habitat, and the planting of native aquatic macrophytes in the constructed base flow channel would be performed to compensate for the unavoidable impacts to aquatic resources.

The Texas Historical Commission has concurred with the Government's determination that the proposed action would have no effect on cultural resources.

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis

Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan. The preferred plan would not adversely impact any state or federal species listed or proposed for listing as endangered or threatened.

A Joint Public Notice of Availability, between the Corps of Engineers and the Texas Natural Resources Conservation Commission, has been prepared to notify the public of this action and to solicit comments. The Public Notice of Availability and copy of the draft feasibility report enclosed with this communication are for your review and to solicit any additional comments or concerns your agency may have regarding this action. We will consider any additional comments that we receive from you by the close of the comment period as indicated on the Public Notice of Availability. A public meeting, for discussion and review of this proposal, has been scheduled for August 16, 2001 at 6:00 p.m. at the Adam Street Community Center in Brownwood, Texas. Please address comments to the contact indicated in the Public Notice of Availability. Thank you for your cooperation in this matter.

Sincerely,

Paul M. Hatton

for William Fickel, Jr.
Chief, Planning, Environmental and
Regulatory Division

Enclosures

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

August 03, 2001

Planning, Environmental, and Regulatory Division

Mr. Thomas J. Cloud, Jr.
United States Department of Interior
Fish and Wildlife Service
Ecological Services
Stadium Centre Building
711 Stadium Drive, Suite 252
Arlington, TX 76011

Dear Mr. Cloud:

The Fort Worth District in conjunction with the City of Brownwood, Texas, proposes construction of has requested approval for a local flood damage reduction project of Willis Creek within the city limits of Brownwood, Texas. The USACE, Fort Worth District has conducted an environmental assessment (EA) and prepared a draft Finding of No Significant Impacts (FONSI) for construction of the proposed plan.

The alternative preferred by the city, designated the "recommended" alternative, and one other alternative was evaluated for the proposed action. The preferred action by the city would be to construct a channel modification consisting of 15,680 feet of hydraulic channel modification on Willis Creek within the city of Brownwood. The recommended plan consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. Approximately 96 acres of reforestation would be undertaken to mitigate habitat removed by the channel modification. The non-structural alternative of floodplain evacuation was also examined; however, the alternative was not feasible due to disruption of community cohesion and lack of sponsorship. The channel modification of Willis Creek was identified as the NED plan.

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A Joint Public Notice of Availability, between the Corps of Engineers and the Texas Natural Resources Conservation Commission, has been prepared to notify the public of this action and to solicit comments. The Public Notice of Availability and copy of the draft feasibility report enclosed with this communication are for your review and to solicit any additional comments or concerns your agency may have regarding this action. We will consider any additional comments that we receive from you by the close of the comment period as indicated on the Public Notice of Availability. A public meeting, for discussion and review of this proposal, has been scheduled for August 16, 2001 at 6:00 p.m. at the Adam Street Community Center in Brownwood, Texas. Please address comments to the contact indicated in the Public Notice of Availability. Thank you for your cooperation in this matter.

Sincerely,

Paul M Hatton

for William Fickel, Jr.
Chief, Planning, Environmental and
Regulatory Division

Enclosure

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF:

August 03, 2001

Planning, Environmental, and Regulatory Division

Mr. Robert Spain
Resource Protection Division
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, TX 78711

Dear Mr. Spain:

The Fort Worth District in conjunction with the City of Brownwood, Texas, proposes construction of has requested approval for a local flood damage reduction project of Willis Creek within the city limits of Brownwood, Texas. The USACE, Fort Worth District has conducted an environmental assessment (EA) and prepared a draft Finding of No Significant Impacts (FONSI) for construction of the proposed plan.

The alternative preferred by the city, designated the "recommended" alternative, and one other alternative was evaluated for the proposed action. The preferred action by the city would be to construct a channel modification consisting of 15,680 feet of hydraulic channel modification on Willis Creek within the city of Brownwood. The recommended plan consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. Approximately 96 acres of reforestation would be undertaken to mitigate habitat removed by the channel modification. The non-structural alternative of floodplain evacuation was also examined; however, the alternative was not feasible due to disruption of community cohesion and lack of sponsorship. The channel modification of Willis Creek was identified as the NED plan.

Construction of the recommended plan would adversely impact approximately 13,336 linear feet of jurisdictional waters of the United States. In the draft Fish and Wildlife Coordination Act Report, dated 23 May 2001, the U.S.

Fish and Wildlife Service recognized that the Willis Creek Flood Damage Reduction Project would adversely impact high quality terrestrial and aquatic resources. For adverse impacts to terrestrial resources, the U.S. Fish and Wildlife Service recommended the acquisition and management of approximately 96 acres of mitigation lands consisting of grassland/old fields and bottomland hardwoods contiguous to the project area.

The mitigation plan for adverse impacts to the terrestrial resources of Willis Creek resulting from the recommended channel modification would consist of converting 80 acres of grassland/old field to bottomland hardwood habitat and restoring 16 acres of native grasslands. The mitigation areas would be located at the Brownwood Municipal Airport and Riverside Park North (Craven's Estate). Planting a minimum of 100 hardwood, mast-producing trees and 50 fruit-bearing shrubs per acre, would be planted for conversion of grassland/old field habitat. Restoration of the native grasslands would require the planting of a variety of native grass and forb species that are native to Texas and have proven wildlife food and cover value. Planting a mixture of native grasses and forbs to stabilize soils on newly constructed channel side slopes would also be performed. Several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for wildlife. Construction of a base flow or low-flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity, the placement of ten, low-water retention structures at base grade along the stream to create pool habitat, and the planting of native aquatic macrophytes in the constructed base flow channel would be performed to compensate for the unavoidable impacts to aquatic resources.

The Texas Historical Commission has concurred with the Government's determination that the proposed action would have no effect on cultural resources.

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan. The preferred plan would not adversely impact any state or federal species listed or proposed for listing as endangered or threatened.

A Joint Public Notice of Availability, between the Corps of Engineers and the Texas Natural Resources Conservation Commission, has been prepared to notify the public of this action and to solicit comments. The Public Notice of Availability and copy of the draft feasibility report enclosed with this communication are for your review and to solicit any additional comments or concerns your agency may have regarding this action. We will consider any additional comments that we receive from you by the close of the comment period as indicated on the Public Notice of Availability. A public meeting, for discussion and review of this proposal, has been scheduled for August 16, 2001 at 6:00 p.m. at the Adam Street Community Center in Brownwood, Texas. Please address comments to the contact indicated in the Public Notice of Availability. Thank you for your cooperation in this matter.

Sincerely,

Paul M Hatton

William Fickel, Jr.
Chief, Planning, Environmental and
Regulatory Division

Enclosures

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

AUGUST 03, 2001

Planning, Environmental, and Regulatory Division

Mr. Robert Lawrence
Office of Planning and Coordination
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, TX 75202

Dear Mr. Lawrence:

The Fort Worth District in conjunction with the City of Brownwood, Texas, proposes construction of has requested approval for a local flood damage reduction project of Willis Creek within the city limits of Brownwood, Texas. The USACE, Fort Worth District has conducted an environmental assessment (EA) and prepared a draft Finding of No Significant Impacts (FONSI) for construction of the proposed plan.

The alternative preferred by the city, designated the "recommended" alternative, and one other alternative was evaluated for the proposed action. The preferred action by the city would be to construct a channel modification consisting of 15,680 feet of hydraulic channel modification on Willis Creek within the city of Brownwood. The recommended plan consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth will vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping will be utilized to minimize costs and environmental impacts while achieving the design slope angles. Approximately 96 acres of reforestation would be undertaken to mitigate habitat removed by the channel modification. The non-structural alternative of floodplain evacuation was also examined; however, the alternative was not feasible due to disruption of community cohesion and lack of sponsorship. The channel modification of Willis Creek was identified as the NED plan.

Construction of the recommended plan would adversely impact approximately 13,336 linear feet of jurisdictional waters of the United States. In the draft Fish and Wildlife Coordination Act Report, dated 23 May 2001, the U.S. Fish and Wildlife Service recognized that the Willis Creek Flood Damage Reduction Project would adversely impact high quality terrestrial and aquatic resources. For adverse impacts to terrestrial resources, the U.S. Fish and Wildlife Service recommended the acquisition and management of approximately 96 acres of mitigation lands consisting of grassland/old fields and bottomland hardwoods contiguous to the project area.

The mitigation plan for adverse impacts to the terrestrial resources of Willis Creek resulting from the recommended channel modification would consist of converting 80 acres of grassland/old field to bottomland hardwood habitat and restoring 16 acres of native grasslands. The mitigation areas would be located at the Brownwood Municipal Airport and Riverside Park North (Craven's Estate). Planting a minimum of 100 hardwood, mast-producing trees and 50 fruit-bearing shrubs per acre, would be planted for conversion of grassland/old field habitat. Restoration of the native grasslands would require the planting of a variety of native grass and forb species that are native to Texas and have proven wildlife food and cover value. Planting a mixture of native grasses and forbs to stabilize soils on newly constructed channel side slopes would also be performed. Several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for wildlife. Construction of a base flow or low-flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity, the placement of ten, low-water retention structures at base grade along the stream to create pool habitat, and the planting of native aquatic macrophytes in the constructed base flow channel would be performed to compensate for the unavoidable impacts to aquatic resources.

The Texas Historical Commission has concurred with the Government's determination that the proposed action would have no effect on cultural resources.

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan. The preferred plan would not adversely impact any state or federal species listed or proposed for listing as endangered or threatened.

A Joint Public Notice of Availability, between the Corps of Engineers and the Texas Natural Resources Conservation Commission, has been prepared to notify the public of this action and to solicit comments. The Public Notice of Availability and copy of the draft feasibility report enclosed with this communication are for your review and to solicit any additional comments or concerns your agency may have regarding this action. We will consider any additional comments that we receive from you by the close of the comment period as indicated on the Public Notice of Availability. A public meeting, for discussion and review of this proposal, has been scheduled for August 16, 2001 at 6:00 p.m. at the Adam Street Community Center in Brownwood, Texas. Please address comments to the contact indicated in the Public Notice of Availability. Thank you for your cooperation in this matter.

Sincerely,

Paul M Hathorn

William Fickel, Jr.
Chief, Planning, Environmental and
Regulatory Division

Enclosures

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF:

August 03, 2001

PUBLIC NOTICE
U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT
AND
TEXAS NATURAL RESOURCES CONSERVATION COMMISSION

CHANNEL MODIFICATION, WILLIS CREEK
CITY OF BROWNWOOD
BROWN COUNTY, TEXAS

Interested parties are hereby notified that the U.S. Army Engineer District, Fort Worth, and the City of Brownwood propose to construct a channel modification of Willis Creek within the city limits of Brownwood. The channel modification would be located along Willis Creek, with the upper segment beginning near Asbury Street and extending downstream to a point approximately 1600 feet east of Quail Creek Court.

Authority.

This notice is being issued to all interested parties in accordance with the National Environmental Policy Act, Public Law 91-190, and Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA), 40 CFR 1500-1508. The project implementation is authorized under the 1968 Flood Control Act, as amended.

Purpose and Background.

The purpose of this channel modification to Willis Creek is to reduce the frequent flooding and reduce the consequent flood damages to those who reside within the floodplain of Willis Creek within the city of Brownwood. Willis Creek originates about five miles southwest of Brownwood and flows generally north and then east, passing through the southern portion of Brownwood, to its confluence with Pecan Bayou southeast of the city. The total drainage area of Willis Creek is 28.42 square miles.

Proposed Action and Alternatives.

Alternatives that were considered to the proposed action by the city included 1) a no action plan which would leave things as they are, and 2) floodplain evacuation plan. Permanent evacuation of structures from the flood plain was considered for the proposed project. An evaluation of removal of structures within the 1, 10, and 50 percent Annual Chance of Excedence (ACE) flood plains resulted in benefit-to-cost ratios of 0.5, 0.7, and 1.0, respectively. There was no sponsor interest in pursuing lower level or partial protection for a smaller number of structures without affecting community cohesion. The alternatives to permanently remove structures from the flood plain were therefore eliminated from consideration. The proposed flood damage reduction project consists of 15,680 feet of hydraulic channel modification on Willis Creek within the city of Brownwood. The proposed modification consists of a grass-lined trapezoidal channel with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet with pilot channel. The channel depth would vary between 4 and 11-feet with the top width varying between 40 to 135 feet. Alternating bank sloping would be utilized to minimize costs and environmental impacts while achieving the design slope angles. The upper segment of the modification would begin near Asbury Street, and extend approximately 6,400 feet downstream (about 1,200 feet downstream of 14th Street). At this point, a diversion channel would be excavated across an open field, reconnecting to Willis Creek about 2,000 feet downstream (approximately 500 feet upstream of 4th Street). The modified channel would continue downstream, approximately 7,880 ft to the terminus of the plan approximately 1600 feet east of Quail Creek Court. The proposed modification would primarily follow the existing creek alignment with the exception of several creek bends that would be bypassed with exception of the 2000-foot diversion channel between 14th Street Bridge and 4th Street Bridge. The bypassed creek bends would be preserved within the channel with base flows to provide for deeper pools and ripples to act as wetlands and provide wildlife habitat. Approximately 96 acres of reforestation and native grassland restoration would be undertaken to mitigate habitat removed by the channel excavation. The modification would also require box culvert modifications to the 14th Street and 4th Street bridges, side slope modifications at the Austin Avenue Bridge, and some storm drain and utility relocations. Riprap will be placed at the bridge approaches for erosion protection. A vicinity map illustrating the proposed action is enclosed.

Construction of the proposed plan would adversely impact approximately 13,336 linear feet of jurisdictional waters of the United States. In the draft Fish and Wildlife Coordination Act Report, dated 23 May 2001, the U.S. Fish and Wildlife Service recognized that the Willis Creek Flood Damage Reduction Project would adversely impact high quality terrestrial and aquatic resources. For adverse impacts to terrestrial resources, the U.S. Fish and Wildlife Service recommended the acquisition and management of approximately 96 acres of mitigation lands consisting of grassland/old fields and bottomland hardwoods contiguous to the project area.

The mitigation plan for adverse impacts to the terrestrial resources of Willis Creek resulting from the recommended channel modification would consist of converting 80 acres of grassland/old field to bottomland hardwood habitat and restoring 16 acres of native grasslands. The mitigation areas will be located at the Brownwood Municipal Airport and Riverside Park North (Craven's Estate). A minimum of 100 hardwood, mast-producing trees and 50 fruit-bearing shrubs per acre, would be planted for this conversion of grassland/old field habitat. Restoration of the native grasslands would require the planting of a variety of native grass and forb species that are native to Texas and have proven wildlife food and cover value. A mixture of native grasses and forbs would also be planted to stabilize soils on newly constructed channel side slopes. Several bypassed bends will be planted with native grasses and forbs adapted for inundations and suitable for wildlife. Construction of a base flow or low-flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity, the placement of ten, low-water retention structures at base grade along the stream to create pool habitat, and the planting of native aquatic macrophytes in the constructed base flow channel would be performed to compensate for the unavoidable impacts to aquatic resources.

Adverse impacts to the aquatic resources of Willis Creek would occur due to diminished water quality, removal of aquatic habitat, and direct mortality of aquatic life. The proposed channel modification would create water quality and habitat conditions that would be incapable of supporting many sensitive aquatic plants, invertebrates and vertebrates. Initially, the aquatic species composition in Willis Creek would resemble that of a disturbed environment. The adverse impacts of implementing this alternative would be mitigated somewhat through avoiding areas of the creek in the bends and maintaining base water flow through the preserved areas during normal flow periods. The avoidance action would help to maintain the overall aquatic species diversity by providing refugia with environmental conditions capable of supporting sensitive aquatic species. The State Historic Preservation Office has concurred with the Government's determination that the proposed action would have no effect on cultural resources.

Section 404, Clean Water Act.

The proposed project has been reviewed in accordance with Section 404(b)(1) guidelines (40 CFR Part 230) promulgated by the U.S. Environmental Protection Agency pursuant to Section 404 of the Clean Water Act for evaluation of the discharge of dredged and fill material into waters of the United States. The possible consequences of the recommended plan have been considered in accordance with regulations published in 33 CFR Parts 320 and 330 and 40 CFR part 230. On the basis of the guidelines set forth in ER 1105-2-100 and 40 CFR Part 230 for a Section 404(b)(1) evaluation (Guidelines for Specification of Disposal Sites for Dredged or Fill Material), the recommended plan for the Willis Creek Flood Damage Reduction Project would be specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem and to implement and abide by the mitigation plan in this document.

Section 401 of the Clean Water Act (33 U.S.C. 1341) requires that any activity which could result in a discharge of a pollutant into waters of the United States obtain a certification from the State in which the discharge would originate and that the discharge comply with applicable effluent limitations and water quality standards. The recommended plan for Willis Creek would be considered a Tier II project as detailed in the "Memorandum of Agreement Between the U.S. Army Corps of Engineers and the TNRCC. A Joint Public Notice for this project between the Corps and the TNRCC to inform the public and governmental agencies would be used to initiate a 30-day comment period for the TNRCC certification. **Any comments concerning the water quality certification must be submitted to the Executive Director, Attention: 401 Coordinator, Research and Environmental Assessment Section, Water Planning and Assessment Division, Texas Natural Resource Commission, 1700 North Congress, P.O. Box 13087, Capitol Station, Austin, Texas 78711.** The public comment period extends 30 days from the date of this notice. The TNRCC may conduct a public hearing to consider all comments concerning water quality if requested in writing. A request for a public hearing must contain the following information: the name of the proposed project, a brief description of the interest of the requestor, or of persons represented by the requestor; and a brief description of how the proposed project, if approved, would adversely affect such interest. This public review period will be the same one used for NEPA compliance. A decision of denial or approval of this project for Section 401 water quality certification would be rendered at the end of the public review.

The environmental aspects of the project proposed by the city and alternatives were considered in an Environmental Assessment (EA) prepared by the U.S. Army Corps of Engineers, Fort Worth District. A Draft Finding of No Significant Impact (FONSI) has also been prepared which, pending receipt of comments to the contrary, will be finalized at the end of the comment period 30 days from the date of this notice. A public meeting, for discussion and review of this proposal, has been scheduled for August 16, 2001 at 6:00 p.m. at the Adam Street Community Center in Brownwood, Texas.

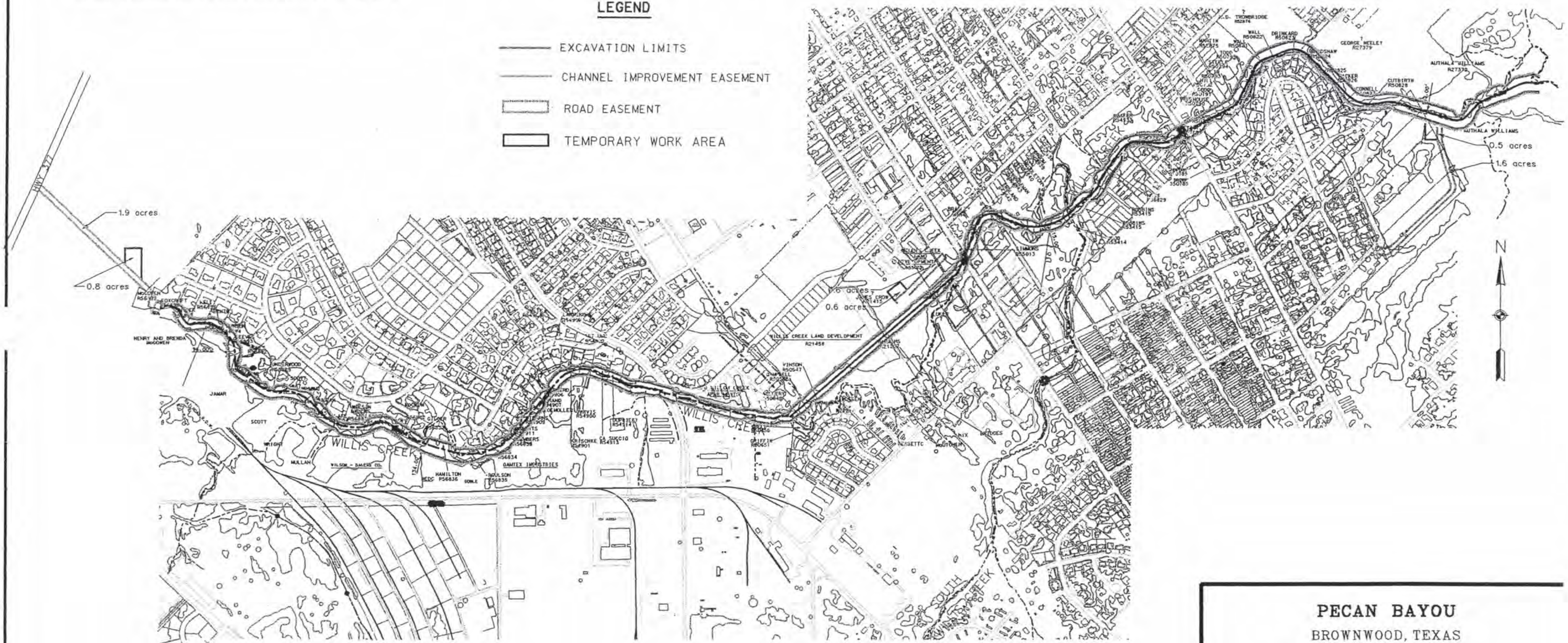
A copy of the report, including the EA and draft FONSI, will be available at the City Hall for Brownwood, 501 Center Avenue, the Brownwood Public Library, 600 Carnegie Boulevard, and at the Corps of Engineers, Fort Worth District, 819 Taylor Street, Fort Worth, Texas 76102-0300. Also, major portions of the EA will be available on the Fort Worth District Website, http://www.swf.usace.army.mil. A limited number of copies are available for distribution to interested parties. Please address any comments to the Fort Worth District, Project Management Division, Post Office Box 17300, Fort Worth, Texas 76102-0300. For further information, contact Mr. Tom Vogt at (817) 978-2669.

for Gordon M. Wells
Colonel, Corps of Engineers
District Engineer

CHANNEL IMPROVEMENT .... 60 ACRES
EASEMENT

TEMPORTY WORK AREA .... 1.9 ACRES

ROAD EASEMENT................4.1 ACRES



PECAN BAYOU

BROWNWOOD, TEXAS

WILLIS CREEK CHANNEL IMPROVEMENT

REAL ESTATE

March 13, 2002

Planning, Environmental, and Regulatory Division

SUBJECT: Proposed Flood Damage Reduction Project of Willis Creek, Brownwood Texas

Mr. Lawrence Oakes
State Historic Preservation Officer
Texas Historical Commission
P.O. Box 12276, Capitol Station
Austin, Texas 78711

Dear Mr. Oakes:

An initial coordination letter was sent to you on August 3, 2001 regarding the above referenced project. That letter incorrectly stated that a cultural resources survey had been conducted in the project area. Your comment letter dated September 14, 2001 pointed out this discrepancy. We appreciate your comments. To clarify our intent regarding this project, we are reinitiating consultation with your office.

The revised Environmental Assessment (see enclosure) indicates no known cultural resources in the proposed project area, but a high probability that intact cultural resources may be deeply buried in the area. A survey augmented by deep testing has been recommended for the area. The work will be conducted by the Fort Worth District during the plans and specifications phase of the project, at which time we will initiate further consultation regarding the exact scope of work for the cultural resources investigations.

Should you have questions or require additional information regarding this project, please contact Ms. Michelle Dippel, Project Archeologist at (817) 886-1719.

Sincerely,

William Fickel, Jr.
Chief, Planning, Environmental, and
Regulatory Division

Enclosure

Ms. Dippel/6-1719
METZ, CESWF-PER-EC
HATHORN, CESWF-PER-E

TEXAS
HISTORICAL
COMMISSION
The State Agency for Historic Preservation

RICK PERRY, GOVERNOR
JOHN L. NAU, III, CHAIRMAN
F. LAWERENCE OAKS, EXECUTIVE DIRECTOR

September 14, 2001

William Fickel, Jr.
Chief, Environmental Division
CESWF-EV-EC
Dept. of the Army
Ft. Worth District, Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Re: Review under Section 106 of the National Historic Preservation Act
Draft Interim Feasibility Report and Environmental Assessment
Pecan Bayou Watershed, Brownwood Texas (COE-FWD)

Dear Mr. Fickel:

Thank you for allowing us to review the draft document referenced above. This letter serves as comment on the document from the State Historic Preservation Officer, the Executive Director of the Texas Historical Commission.

The review staff, led by Bill Martin, has completed its review. Although the cover letter specifically states that a detailed cultural resources survey was completed and that there are no historic properties within the project area, the report states otherwise. In fact, several places in the document, it specifically states that no archeological survey, other than a brief reconnaissance, has taken place. Based on the results of the reconnaissance, the report states that it is highly likely that cultural resources could be found throughout the area, and survey using mechanical trenching is recommended.

If a survey was conducted subsequent to this feasibility study, please send us the report so that we may review it. Otherwise, given the lack of identification efforts, we cannot concur that there will be no adverse effect on historic properties as a result of this undertaking.

Thank you for your cooperation in this federal review process, and for your efforts to preserve the irreplaceable heritage of Texas. **If we may be of further assistance, please contact Bill Martin at 512/463-5867.**

Sincerely,

for
F. Lawerence Oaks, State Historic Preservation Officer

FLO/wam

P.O. BOX 12276 · AUSTIN, TX 78711-2276 · 512/463-6100 · FAX 512/475-4872 · TDD 1-800/735-2989
www.thc.state.tx.us

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
WinSystems Center Building
711 Stadium Drive, Suite 252
Arlington, Texas 76011

August 13, 2001

Colonel Gordon M. Wells
District Engineer
(Attn: Dr. Hank Jarboe, CESWF-EV-ER)
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Colonel Wells:

We have recently reviewed the Public Notice, draft Finding of No Significant Impact (FONSI), and Environmental Assessment (EA) regarding the environmental impacts of the proposed flood damage reduction project on Willis Creek within the city limits of Brownwood, Brown County, Texas. The proposal is to construct a channel modification with side slopes of 1 vertical to 3.5 horizontal and a bottom width of 40 feet. The channel depth will vary between 4 and 11 feet with the top width varying between 40 and 135 feet. One-sided channel construction would be used to minimize impacts on the environment, where possible. The preferred action would also include an approximately 2,000 linear foot diversion channel that would be excavated across an open field to avoid a section of high quality wildlife habitat along the creek. The proposed project would include implementation of a mitigation plan to mitigate impacted natural resources.

Several alternative solutions for reducing flood damage from Willis Creek in the City of Brownwood were considered and discussed in the EA. The alternatives evaluated were both non-structural and structural in nature. Non-structural alternatives considered included floodplain management, flood forecast warning, flood proofing, floodplain evacuation, and the no-action alternative. Structural alternatives considered included detention, levees and floodwalls, and hydraulic channel and/or bridge modifications. Due to high price, impracticality, or environmental consequences, reasonable alternatives justifying further study and detailed analysis were the non-structural alternatives of floodplain evacuation and the no-action alternative as well as the structural alternative of hydraulic channel and/or bridge modifications. According to the EA, the floodplain evacuation alternative was not feasible due to disruption of community cohesion and lack of sponsorship. The channel modification plan provided greater comprehensive flood protection, higher net benefits, and was identified as the National Economic Development (NED) plan.

Specific Comments

The following specific comments concerning the Willis Creek draft Interim Feasibility Report and Integrated Environmental Assessment (Report) are provided for your consideration.

Page 45. Disposal Sites.
The City of Brownwood has established locations for the disposal of excess excavated overburden and waste material. Currently, the City's plan includes the removal of debris material from brush and tree clearing to an off-site disposal area located approximately three to five miles from the proposed project site. One recommendation provided in the draft FWCA report was to provide or enhance escape, resting, and nesting cover by introducing nest boxes, brush piles, stumps, logs, large boulders, or other similar habitat features on the proposed 96-acre mitigation area. We suggest the City and the Corps investigate the potential for using some debris material from brush and tree clearing on-site within the mitigation area to construct these habitat features instead of removing the material to an off-site disposal area. We recommend the placement of one structure per acre to compensate for the loss of this habitat component within the footprint of the proposed project. Additional information regarding the design and construction of the structures is available upon request.

Page 46. Environmental Mitigation.
According to the Report, the Corps believes there is not an anticipated disturbance from livestock or human activities. We do not agree with the Corps' decision to remove fencing costs from the mitigation plan estimate. During a site visit in September 2000 to select potential mitigation sites, we determined that the airport and Riverside Park North (Craven's Estate) properties had the most potential to compensate for the proposed project impacts. While on the site visit, we observed unauthorized citizens living in a shelter on the Craven's Estate and evidence of past livestock grazing on the airport property. Therefore, we continue to recommend that fencing be included as a required component of the environmental mitigation plan, since activities similar to those observed on site could drastically influence the success of the riparian/ bottomland hardwood reforestation and native grassland restoration program.

Page 57. Operation, Maintenance, Repair, Rehabilitation, & Replacement.
In the discussion concerning "Operation and Maintenance", it is not clear whether the total annual cost of operation and maintenance (O & M) of the mitigation area is included in the $15,600 estimate. We have estimated the O & M of the mitigation area to be approximately $40 per acre. Our estimate includes mowing the mitigation lands during late fall or early winter until the reestablishment of woody vegetation is deemed successful. It also includes other activities that may be required to insure the successful reestablishment of bottomland hardwoods and native grasslands (e.g., the use of growth hormones, slow release fertilizers, protective sleeves, adequate irrigation, etc...). Therefore, if these costs were not included in the total annual cost, we recommend that the Corps add approximately $3,840 to the overall annual cost for O & M of the completed project.

As stated in the O & M discussion, "the total annual cost includes such activities as mowing (three times yearly) to regulate grass height and reduce growth buildup, bi-annual fertilizing of the grass to maintain adequate groundcover and prevent erosion, annual herbicidal applications as needed to control woody growth, general maintenance and clean-up, and the removal of sediment buildup throughout the channel." An integral part of the mitigation plan for adverse impacts to the fish and wildlife resources of Willis Creek includes: the use of native grasses and forbs on the side slopes of the newly constructed channel and several bypassed bends; the construction of a base flow channel (approximately 15 feet wide and 2.5 feet deep) that mimics the streams' original sinuosity; the placement of 10 low-water retention structures at base grade along the stream to create pool habitat; and the planting of native aquatic macrophytes in the base flow channel. Due to the large number of maintenance and mitigation activities proposed in the channel, we believe it is imperative the City of Brownwood clearly understands their responsibilities for O & M. Specifically, what they are allowed to maintain within the channel and how they are required to maintain it.

For example, we recognize that steep slopes and high velocity areas may require the use of dense sod-forming grasses, such as Bermudagrass, but recommend non-critical sites (i.e., those areas not subject to high erosional forces) should be planted with native grasses and forbs for improved wildlife values. The City of Brownwood should be aware of the different maintenance requirements of these areas and proceed accordingly. Mowing and other maintenance activities on areas within and/or near the channel included in the mitigation plan should be restricted to the late fall and winter months. Furthermore, we do not believe any maintenance activities should occur within the base flow channel once it is constructed.

We appreciate the opportunity to provide input on the proposed action and look forward to future coordination for resolution of our concerns. Please contact Mike Armstrong of my staff at (817) 277-1100 for further coordination and assistance.

Sincerely,

Tom Cloud

Thomas J. Cloud, Jr.
Field Supervisor

cc: Complex Supervisor, FWS, Austin, Texas

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

August 23, 2001

Planning, Environmental, and Regulatory Division

Mr. Thomas J. Cloud, Jr.
Field Supervisor
United States Department of the Interior
Fish and Wildlife Service
Ecological Services
711 Stadium Drive, Suite 252
Arlington, Texas 76011

Dear Mr. Cloud:

Thank you for your comments dated August 13, 2001, on the Public Notice, draft Finding of No Significant Impact (FONSI), draft Detailed Project Report (DPR), and Environmental Assessment (EA) regarding the environmental impacts of the proposed flood damage reduction project on Willis Creek within the city limits of Brownwood, Texas.

Responses to your specific comments are provided in the following subparagraphs:

a. Comment 1: Disposal Sites. The Corps considers the Fish and Wildlife Service (FWS) recommendation regarding the use of construction related material from brush and tree clearing for the development of wildlife habitat to be valuable. The Corps is in full support of this recommendation and we will indicate it to be a requirement of mitigation, that woody construction debris from the Willis Creek project be windrowed within the mitigation area. This information will be included in the DPR within the discussion of mitigation activities. We would welcome all suggestions from the FWS on how to effectively integrate the windrows among the other specific activities that have been proposed for mitigation in this project.

b. Comment 2: Environmental Mitigation. The Corps would agree that the potential for future disturbance either by livestock or human activities in the mitigation areas could be minimized through the use of fencing. We therefore accept and support the recommendation by the FWS that fencing be included as a required component of the mitigation plan and will also include fencing as a project cost.

c. Comment 3: Operation, Maintenance, Repair, Rehabilitation, & Replacement (OMRR&R). Although not specifically itemized, the cost estimate for OMRR&R of the mitigation of the area is included within the estimate of $15,600, which has been provided for the project. The Corps respects the concerns that the FWS has expressed regarding the level of understanding that the sponsor has of their OMRR&R responsibilities for mitigation. The

OMRR&R for this project will be clearly stated in a manual that will be provided to the sponsor upon completion of the project. Additionally, annual inspections of the project (inclusive of the mitigation area) will be conducted to ensure that compliance with required OMRR&R is met. We appreciate the estimate that the FWS has provided for approximate operation and maintenance cost of the mitigation area, and will use this in an effort to define the overall costs for this project.

We look forward to further close coordination with the FWS on the future activities associated with the Willis Creek flood damage reduction project. Please contact Dr. Hank Jarboe of my staff at (817) 978-5068 for further coordination and assistance.

Sincerely,

William Fickel, Jr.
Chief, Planning, Environmental,
and Regulatory Division

CESWF-PER-PF, Jarboe
CESWF-PER-PF, Kangas
CESWF-PER-P, Griffith
CESWF-PER, Fickel

PECAN BAYOU WATERSHED
BROWNWOOD, TEXAS
FEASIBILITY PHASE

QUALITY CONTROL PLAN

The Pecan Bayou watershed, Brownwood, Texas, feasibility phase was initiated prior to the District receiving delegated authority to approve the technical adequacy of its products. Consequently, a quality control plan was never specifically developed for this study. However, a "District" quality control plan has been adopted by the District and approved by Southwest Division.

This feasibility study has been ongoing for an extended period of time. Turnover of study team members, immediate supervisors, middle and upper management, coupled with various district reorganizations and the relocation of several offices, has resulted in less than ideal documentation of the study progress, issues and questions addressed, and decision-making process.

Regardless, several layers of technical review, including managerial oversight, have been completed throughout the last five years of the study. However, the last semi-documented review occurred after the first draft Alternative Formulation Briefing was completed in June 00. This documentation is available for review.

From this point forward, the quality control plan identifies the requirement for a technical review of each appendix and the main report. The technical review of the each appendix will be "independent" to the maximum extent possible, given the availability of in-house resources. This process is as follows:

- Reviewer will examine appendix and background material, including but not limited to methodology of analysis, computer models, computations, assumptions made, interpretations of data, etc.

- Reviewer will document specific comments and forward to team member.

- Team member will review comments and document response.

- Comments and responses, as well as a signed statement from the functional immediate supervisor attesting to the adequacy of the product will be transmitted to the Lead Planner and held in the file prior to the completion of the main report.

- The draft main report will also receive a review similar in process to the appendices. The main report review will be completed by members of the study team, immediate supervisors, Branch and Division chiefs. This review will culminate with the signing of a "Certificate of Technical Review" by the Division Chiefs and the District Commander, and included as part of the final report.

Quality Control Plan

A. Introduction

Effective 1 Oct. 95, the Southwestern Division and HQUSACE no longer review planning reports for technical adequacy. This responsibility has been placed with the District producing the report. Although SWD and HQUSACE will not conduct a technical review, they will review reports for conformance to current policy. As such, the Fort Worth District is responsible to ensure that its report conforms to all current professional practices and standards by conducting an independent technical review of the report, prior to its submission to SWD and HQUSACE. Policies and procedures defining the quality control / internal technical review process are specified in EC 1165-2-203, "Technical and Policy Compliance Review", 15 October 1996.

B. Quality Control / Internal Technical Review Responsibilities

The goal of the technical review process is to ensure that the report and its sub-components meet the technical standards and regulations of the Corps of Engineers. The Fort Worth District is responsible for the independent technical review of the feasibility study and its products and will develop and implement a QC plan for the project. The QC plan includes the independent technical review of decision and implementation documents, consistent with established criteria, guidance, procedures, and policy; and identifies how the district plans to ensure compliance with technical and policy requirements.

C. Technical Review Process

Technical review is part of the overall development of implementation and decision documents and is the systematic execution of actions, decisions, and reviews taken during the concept development, formulation of alternatives, and project design phases to ensure conformance with laws and Administration policy. An independent technical review is conducted for all decision and implementation documents and is independent of the technical production of the project/product. The selected independent technical review methods are identified in this QC plan. The technical review team members have the proper knowledge, skills, and experience necessary to perform their tasks and are independent of the study team responsible for the development of the project/product. The QC/QA process is described herein will be fully documented in the feasibility study. Documentation and certification of technical/legal review will accompany the Feasibility Report that is submitted to SWD and HQUSACE for policy compliance review.

The Fort Worth District will apply all appropriate technical and policy guidance in developing the Pecan Bayou Feasibility Report. Since the district is responsible for both conducting the work and providing the technical review of the work, the technical review will be independent. Independent review will include review of all the technical work and products from plan formulation, environmental, economics, engineering, cost estimating, real estate, and other disciplines that are essential to achieving a quality Feasibility Report.

Corps of Engineers criteria will be used to judge the technical adequacy of the products and documentation will be accomplished by written comments, responses and correspondence. Each technical element will schedule sufficient time for a technical review to allow their appendix to be submitted in accordance with the currently approved PSP. In order to accomplish this, each technical element will conduct its quality control on a continual basis with each major sub-product serving as a check point in the quality control process. This will ensure that any technical mistakes are found early and resolved while the material is fresh in the minds of those working on it. For work performed by a contractor, each contract scope of work will require several work progress updates and submissions prior to the submission of the draft report and final report. These progress updates will serve to ensure that the contractor is proceeding in the direction that the Corps wishes to pursue and raise any issues that may need to be resolved.

Previously developed checklists will be used in the quality control process to assist the reviewer, but will not be used to replace that persons technical expertise or judgment. The checklists are designed to assist the reviewer in ensuring that the report contains the minimum amount of material necessary to make decisions and that any conclusions drawn in the report are based on the information provided.

Each reviewer will document their comments on review sheets. At a minimum, each comment will refer to the page and paragraph in question, the nature of the problem, where guidance can be found which applies to the problem, and if possible, a suggested solution to the problem. The comments and any checklist used will be returned to the person responsible for the product to resolve. Responses to each comment will provide, at a minimum, what was done to correct the deficiency and where the deficiency was corrected, or a justification for why the deficiency was not corrected. The package of comments and responses will be attached to the final submission as a sub-appendix. It is the responsibility of the section supervisor responsible for the product to review the comments and responses to ensure that all issues are resolved.

Each line supervisor has the responsibility for the day to day quality control of those they supervise. As such, they are directly responsible for checking the day to day work of their subordinates and resolving any issues that the review team members may raise.

D. Additional Quality Control Measures

In addition to the steps described above, three quality control meetings will be held during the course of the study. The purpose of these meetings will be for the Branch Chiefs and other team members to gain an understanding of what the study team has produced and provide comments and raise issues at the appropriate time. The review team members will provide their written comments on the main report at this time. The three briefings are:

1. Without-Project Conditions

2. With-Project Conditions

3. Alternative Selection (Note, this briefing will also include participants from SWD, HQUSACE, the non-Federal sponsor, and Federal and state environmental agencies).

QUALITY CONTROL PLAN

OVERVIEW, BASIC CONCEPTS AND APPLICABILITY

I. Overview

This Quality Control Plan (QCP) has broad application to most of the Fort Worth District General Investigations (GI) Planning functions. This QCP may be expanded, contracted, or otherwise modified based on the risk, cost, complexity and uniqueness of the effort being undertaken. However, this model and each variation is expected to:

A. Explain the concept of how the QCP is integrated with and complements existing structures such as the Project Review Board and existing management tools such as Project Study Plans (PSP) or Project Management Plans (PMP) without usurping the functional responsibilities of PM's , TM's or their chains of command.

B. Establish a concept and process for identifying a specific set of assignments for an independent Technical Review Team not directly involved in the production of the work products to participate in the life-cycle progress of the study/project.

C. Provide a "checklist" or similar tool to aid the Technical Review Team in their mission of assuring that significant items and issues are not overlooked.

II. Basic Quality Control Concept

Quality control is assured by a multi-discipline, multi-layer, life-cycle approach. Successful Planning products are the result of the insights and expertise of a diverse array of professionals, including the active participation of local sponsors and representatives from other pertinent agencies. Work efforts are conducted either by A-E, other districts or by in-house technical staff. If the primary technical work is conducted outside the District, one layer of review will take place by the contractor before transmission the report is transmitted to the Fort Worth District. The District Study/Project Team members will conduct a second layer review of the contractor's work products. The next layer of review involves the Team Leaders or Section Chiefs of the Study Team members to assure some degree of completeness, correctness, and consistency since a portion of the functional responsibility for the end-product lies with the technical worker's first line leader or supervisor. This first-line supervisor is intimately involved in the progress of the effort and will not serve as the Technical Review Team Member for his/her discipline. Branch Chief and Division Chief level (overview/policy) reviews are also conducted and they tend to exhibit a greater degree of independence and objectivity than previous layers since they are not involved in the day-to-day production activities. This layer is routinely accomplished as Division Chiefs provide PRB recommendations and approvals. This QCP establishes a separate, independent Review Team as specified on a subsequent page.

The Quality Control Team (QCT) participates in the entire life-cycle of the study/project:

1. The QCT contributes to and reviews the PSP at its inception.

2. QCT provides an intermediate review as major products/decision are reached.

3. Specific points requiring QCT review are:
    - i). Definition of without-project conditions:
    - ii). Definition of with-project conditions
    - iii) Alternative Formulation and screening of alternative plans.

4. The QCT will provide a thorough review of Draft and Final products and identify and resolve problems in conjunction with the Study Team before recommending PRB approval.

Written comments from the QCT will be addressed to the Study Team for resolution. These comments are compiled as part of the Quality Control Report to indicate the issues and concerns which were raised and addressed along the course of the study. Unusual issues or conflicts which cannot be resolved by the Study and Review Teams may be addressed to an appropriate resource in SWD for guidance.

III. Responsibility

The Review Team is required to certify the results of their review as indicated on the enclosed Certification Form within the Quality Control Report. Study Team members, Technical Managers, Project Managers and Functional Chiefs still retain responsibility for the quality and timely execution of study / project tasks in accordance with milestones, costs and commitments as identified in the PSP. The Review Team provides ancillary quality control, not replacement of existing responsibility for technically accurate, high-quality work products.

IV. Technical Review Team

The Technical Review Team will focus on:

A. Assumptions.

B. Methods, procedures and material used in the analysis based on the study /project scope.

C. Alternatives evaluated.

D. Appropriateness of data used and level of data obtained.

E. Reasonableness of the results, including whether the product meets the customers needs consistent with law and existing policy.

V. Checklists

Previously developed checklists will be utilized for review of Feasibility Reports. These checklists are meant to be available tools to assist the Review Team Member, not to replace his/her technical expertise or judgment.

CHECKLIST FOR REVIEW OF FEASIBILITY REPORTS

1. Has the study been conducted in accordance with and fully responsive to the study authority?

2. Is the study area, as defined, reasonable and consistent with the study authority?

3. Have the area extent and severity of the water-resources problems and without-project conditions been clearly documented?

4. Are current findings consistent with prior phases of study? Have intervening external factors (such as regulation changes, significant storm events, etc.) jeopardized previous logic, analyses and conclusions?

5. Have the assumptions and rationale for the without-project condition been explicitly stated and are they reasonable?

6. Are planning objectives clearly identified?

7. Were the views of non-Federal interests solicited and considered in the plan formulation process?

8. Have all reasonable structural and non-structural plans, including a no-action plan, been considered? Do they fully address the identified problems and needs?

9. Was the plan formulation analysis conducted in accordance with accepted techniques and appropriate guidelines and regulations?

10. Was the environmental work conducted in accordance with appropriate techniques, guidelines and regulations?

11. Was the economic/benefit analysis conducted in accordance with accepted techniques, guidelines and regulations?

12. Has the NED plan been identified? Is it the selected/recommended plan?

13. For environmental restoration efforts, was an cost effectiveness and incremental analysis accomplished? Was resource significance defined?

14. Is there a rationale for a locally-preferred plan or non NED recommended plan?

15. Does the recommended plan meet the customer's needs and has the position of the sponsor been explicitly conveyed?

16. Have upstream and downstream effects of the recommended plan been identified?

17. Have all known benefits been included in the benefit estimate? Have high-priority benefits been identified?

18. Have economic methodologies and assumptions been explained in sufficient detail?

19. Is the evaluation of each alternative based on the difference between the without-project and with-project conditions?

20. Have risk and uncertainty been addressed in accordance with ER 1105-2-101?

21. Has the necessary coordination been conducted and documented in accordance with the National Environmental Policy Act of 1969 (NEPA) and ER 200-2-2?

22. Have HTRW considerations been addressed?

23. Is the proposed project recommendation consistent with current administration policies?

24. Does the over-all Planning report adequately display study assumptions, and findings, as well as and clearly represent a firm basis for the recommendation?

Key Items Addressed by Review Team

a) Validity of technical assumptions
b) Methods and procedures used in the analyses
c) Reasonable alternatives were addressed
d) Appropriateness of data used
e) Reasonableness of the results and responsiveness to customer needs

CESWF-PM-C 23 July 2001

TECHNICAL REVIEW
DOCUMENTATION

1. The Interim Feasibility Report for Pecan Bayou, Brownwood, was completed by Fort Worth District on July 09, 2001 and submitted for in-house technical review.

2. The Technical Review was performed by Fort Worth District personnel and completed on July 20, 2001. The review comments, with appropriate responses and/or references to the report where comments were resolved, are shown as Enclosure 2a.

Jason C Foltyn

Jason Foltyn, Lead Planner

Thomas R. Vogt

Thomas Vogt, Project Manager

Enclosure 1

QUALITY CONTROL REPORT

PECAN BAYOU FEASIBILITY STUDY

Overview

This report synopsizes the Quality Control and Review Process to be employed during the conduct of the feasibility study. In light of the changes in review functions on the Division and Headquarters levels in recent years, the responsibility for review of technical products rests with the district. Each operating Division in the District has developed its own functional procedures and will identify its own Study Team and Review Team members for quality control of its areas of technical expertise.

Study Team and Review Team Assignments

Discipline	Study Team Member (Name)	Review Member (Name)
Plan Formulation / Report Preparation	Eli Kangas / Jason Foltyn	Jerry McCrory / Elston Eckhardt
H&H	Craig Loftin	Lisa Eskew
Civil Design	Larry Mendoza	Efren Martinez
Structural Design	William Sanner	William Wallace
Geotechnical	Ken McCleskey	John Wise
Cost Estimating	Jim Sears	Richard Keene
Economic Analyses	Lanora Wright	Mead Sams
Cultural Analysis	Stephen Austin	Jay Newman
Environmental Analysis	Hank Jarboe	Marty Hathorn
Real Estate	Blake Bryant	Bobby Camp
HTRW	Wayne Elliott	Ted Nicholson

PECAN BAYOU WATERSHED, TEXAS
WILLIS CREEK, BROWNWOOD
FORT WORTH DISTRICT
STUDY TEAM MEMBERS

TEAM MEMBER	SPECIALTY	SIGNATURE	DATE
Thomas Vogt	Project Management	Thomas R. Vogt	18 July 01
Jason Foltyn	Planning	Jason Foltyn	17 July 01
Hank Jarboe	Environmental Resources		19 July 01
Craig Loftin	Hydrology and Hydraulics	Craig H. Loftin	
Lanora Wright	Economics	Lanora Wright	
Blake Bryant	Real Estate		18 Jul 01
Larry Mendoza	Civil Design	Larry Mendoza	18 JUL 01
William Sanner	Structural Design	William O. Sanner	
Ken McCleskey	Geotechnical Design	Ken McCleskey	
Jay Newman	Cultural Resources	Jay R. Newman	
Wayne Elliott	HTRW Resources	Wayne Elliott	7.17.01
Jim Sears	Cost Estimating	Jim Sears	

DISTRICT QUALITY CONTROL CERTIFICATION
STATEMENT OF TECHNICAL AND LEGAL REVIEW

COMPLETETION OF INDEPENDENT TECHNICAL REVIEW

The District has completed the Feasibility Phase Analysis for investigating the purposes of providing flood damage reduction, ecosystem restoration, watershed management, and more effective water management within the Pecan Bayou watershed, Brownwood, Texas. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the Quality Control Plan. During the independent technical review, compliance with established policy principals and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions; methods, procedures, and material used in analysis; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy. Personnel from the Fort Worth District accomplished the independent technical review.

Reviewer	**Branch/Section Chief**	**Signature**	**Date**
Les Perrin	Assistant Chief – Design Branch	Jimmy D. Boggett	7/23/01
Mead Sams	Section Chief - Economics		7/20/01
Darrel Cullens	Section Chief - Civil Design	Darrell Cullens	7/18/01
Bobby Camp	Section Chief - Real Estate	Bobby J. Camp	23 July 0
William Wallace	Section Chief - Structural	William A. Wallace	
John Wise	Section Chief - Geotechnical	John R. Wise	19 JUL 01
Steve Smith	Section Chief – HTRW	Steven W. Smith	7/20/01
Lee Osborne	Section Chief - Cost Estimating	Otto L. Osborne	
Elston Eckhardt	Acting Section Chief – Planning	Elston D. Eckhardt	

DISTRICT QUALITY CONTROL CERTIFICATION
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Reviewer

William Fickel

William Fickel
Chief – Planning, Environmental, and Planning Division

Larry O. Rogers

Larry Rogers
Chief – Engineering & Construction Division

Hyla Head
Chief – Real Estate Division

Rex Crosswhite – Deputy District Council

Jerry A McCrory

Jerry McCrory
Chief – Civil Works, Program and Project Management

Paul M Hathorn

Marty Hathorn
Assistant Division Chief – Planning, Environmental, and Planning Division

Rebecca S Griffith

Rebecca Griffith
Planning Branch Chief – Planning, Environmental, and Planning Division