US Army Corps
of Engineers
Fort Worth District

INTERIM REPORT
AND
ENVIRONMENTAL ASSESSMENT

SHOAL CREEK
AUSTIN, TEXAS

NOVEMBER 1991

DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1114 COMMERCE STREET
DALLAS, TEXAS 75242-0216

REPLY TO
ATTENTION OF:

19 NOV 1991

CESWD-PL-S

MEMORANDUM FOR Commander, U. S. Army Corps of Engineers,
20 Massachusetts Avenue, NW., Washington, DC
20314-1000

SUBJECT: Shoal Creek, Austin, Texas, Interim Feasibility Report and Supporting Documentation

I concur with the recommendations of the District Commander.

Stanley G. Genega

STANLEY G. GENEGA
Brigadier General, USA
Commanding

SHOAL CREEK
AUSTIN, TEXAS

FINAL INTERIM REPORT
AND
ENVIRONMENTAL ASSESSMENT

NOVEMBER 1991

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

SYLLABUS

This report presents the results of studies which identify water and related land resources problems and needs of the Shoal Creek watershed in Austin, Texas, and formulates alternative solutions to alleviate these problems. The area along Shoal Creek has suffered from frequent and severe flooding in the past which caused extensive property damage and loss of life.

The analysis of the flood problems and formulation of structural and nonstructural solutions indicated that Federal participation in a flood damage reduction project along Shoal Creek could be justified. From the analysis of economic, environmental, engineering, and social data, a plan was developed which reduces the damages by approximately 82 percent. Based on the economic analysis, this plan is the National Economic Development (NED) plan and is consistent with the Principles and Guidelines for Planning Water and Related Land Resources Implementation Studies as developed by the U.S. Water Resources Council, dated July 1983.

The NED Plan identified for Shoal Creek is the 14-foot combination tunnel/channel plan and consists of the following improvements on Shoal Creek and Hancock Creek, the major tributary: approximately 1,200 feet of 50-foot bottom width grass-lined channel improvement on Shoal Creek from the MOPAC railroad bridge to U.S. Highway 183; two 11-foot conduits under U.S. Highway 183; 10,200 feet of 30- to 50-foot bottom width grass-lined channel improvement from U.S. Highway 183 to Greenlawn Parkway; a 14-foot diameter tunnel diversion with an intake downstream of Greenlawn Parkway and an outfall at Lake Austin near Bull Creek; a 14-foot diameter diversion tunnel with an intake on Shoal Creek near 19th Street and an outlet close to Town Lake near Pressler Street; 750 feet of grass-lined channel from the tunnel outlet to Town Lake. Recreational development will be provided along the channelization in the upper reaches of Shoal Creek. The plan also includes a 40- to 50-foot bottom width concrete channel along 3,200 feet of Hancock Creek from just upstream of Houston Street to 700 feet downstream of Hancock Drive.

The city of Austin reviewed the NED Plan and, after weighing all of the data provided, the city has made the decision to implement only a portion of the NED Plan. The city of Austin has indicated they would like to proceed with the Hancock Creek portion of the project. This buy-down from the NED plan was therefore the recommended plan.

This plan will require the disposal of approximately 40,500 cubic yards of material. The city of Austin has identified a couple of sites for the disposal of these materials. These sites are located in southeast Austin near the Colorado River. One site is a gravel pit, while another site is located in a relatively undeveloped area in the same general vicinity. Coordination has been maintained throughout the study with the U. S. Fish and Wildlife Service and the Texas Parks and Wildlife Department. The Recommended Plan will not require any mitigation measures for fish and wildlife purposes.

The first cost of the Recommended Plan at February 1991 price levels, is estimated at $6,634,700. Under current guidelines, the city of Austin would be responsible for $1,659,000 and the Federal Government would pay $4,975,700. The city of Austin would be responsible for all operation, maintenance, and replacement costs, estimated to be $5,000 annually. The total annual charges for the Recommended Plan, including operation, maintenance, and replacement costs, is $646,800. Average annual benefits for the Recommended Plan are $1,229,700. These include inundation reduction benefits, vehicular benefits, and reduction in insurance overhead benefits. The resulting benefit-to-cost ratio is 1.9 to 1.0.

SHOAL CREEK
AUSTIN, TEXAS

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ENVIRONMENTAL ASSESSMENT
AND
FINDING OF NO SIGNIFICANT IMPACT

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SHOAL CREEK, AUSTIN, TEXAS
DRAFT INTERIM REPORT

CHAPTER 1
INTRODUCTION

This study was conducted to identify significant water resources needs and problems of the Shoal Creek watershed, and to present plans which would be responsive to them. This report is presented in two parts. The first part contains the main report which provides a general overview of the study, formulation of various alternatives, the results, and project recommendations. The second part contains technical information supporting the main report.

The Shoal Creek watershed is located within the Colorado River Basin in central Texas, in the west central part of the city of Austin. Flow in the watershed travels generally south into the Colorado River. Figure 1-1 shows the location of Shoal Creek in relation to the Colorado River Basin. Shoal Creek meanders through Austin with developments encroaching upon the watercourse in numerous areas. Through the residential areas, large trees, stone revetments, fencing, and mowed yards extend to the creek presenting an attractive area except during periods of flooding. The city of Austin has experienced extensive damages from floodflows on Shoal Creek.

STUDY AUTHORITY

The initial studies were undertaken by the Corps of Engineers to determine Federal interest for participation in a project to alleviate these conditions under the continuing authority provided to the Chief of Engineers by Section 205 of the Flood Control Act of 1948, as amended. The Reconnaissance Report, prepared in December 1981, under that authority, recommended that additional study of the flood problems be accomplished under the Corps' General Investigation Program, specifically under the Colorado River and Tributaries basinwide authority. This study is being accomplished as a partial response to the following Congressional directional.

a. Flood Control Act, approved June 22, 1936:

"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and, surveys for flood control at the following named localities,.....Colorado River, Texas, above the county line between Coke and Runnels Counties....Lower Colorado River, Texas."

b. Resolution by the Committee on Commerce, United States Senate, adopted August 4, 1936:

"Resolved by the Committee on Commerce of the United States Senate, That the Board of Engineers for Rivers and Harbors created under Section 3 of the River and Harbor Act, approved June 13, 1902, be and is hereby, requested to review the reports on Colorado River, Texas, submitted in House Document Number 361, Seventy-first Congress, second session, and previous reports, with a view to determining if improvement in the interest of commerce and flood control is advisable at the present time."

c. River and Harbor Act, approved August 26, 1937:

"Section 4. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys to be made at the following named localities,....Colorado River, and its tributaries, Texas, with a view to its improvement in the interest of navigation and flood control."

d. River and Harbor Act, approved March 2, 1945:

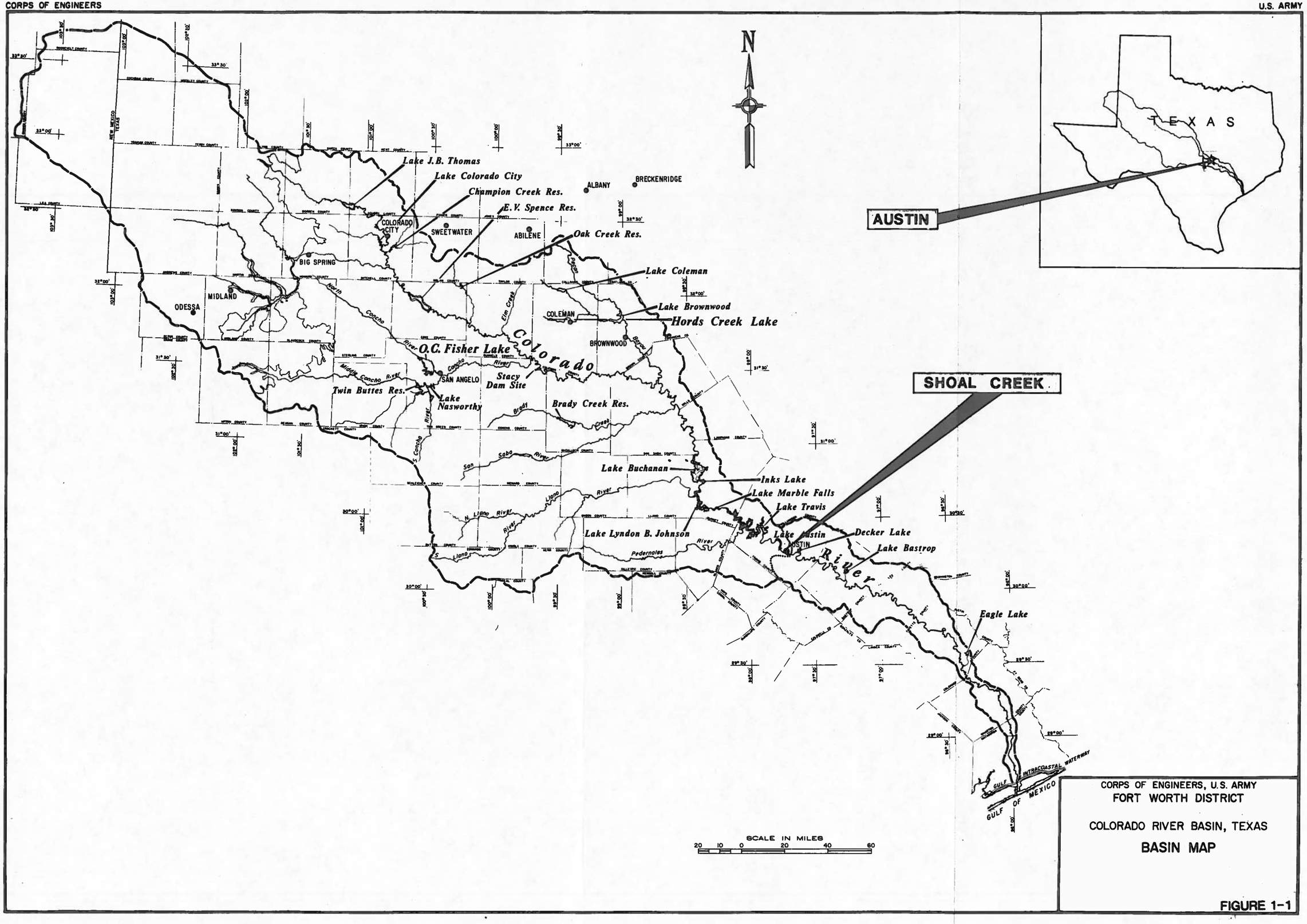
"Section 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys to be made at the following named localities,....Colorado River, Texas."

Several interim reports have been conducted under this basinwide authority. Studies of the Shoal Creek watershed under the basinwide authority were initiated in fiscal year 1983, after studies were requested by the city in response to flooding in the Austin area in May 1981. Flash flooding has occurred through the years with the more damaging storms recorded in April 1915, November 1974, April 1975, May 1981, and May 1987. During May 24-25, 1981, 13 deaths occurred in the Austin area due to drowning, with 5 of these on Shoal Creek.

SCOPE OF STUDY

This study was undertaken pursuant to the above Congressional direction to examine the water and related land resource problems and needs in the Shoal Creek watershed. In this study, both historic flooding and damages were investigated along with the projections for future development and the effects it would have on the problem.

A broad range of alternative measures designed for the prevention of flood-related damages was investigated. Each alternative was developed sufficiently to determine its feasibility and to permit selection of the alternative found most advantageous based on engineering considerations, economic feasibility, needs of the area, and environmental and social acceptability. The alternatives included both structural and nonstructural measures.



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

COLORADO RIVER BASIN, TEXAS

BASIN MAP

FIGURE 1-1

The "Principles and Guidelines for Planning Water and Related Land Resources Implementation Studies (March 1983)" and The National Environmental Policy Act of 1969 (NEPA) provide the basis for Federal policy for planning flood damage reduction projects.

STUDY PARTICIPANTS AND COORDINATION

This study was conducted by the Fort Worth District, Corps of Engineers. Coordination was maintained throughout the study with all Federal, state, and local agencies and organizations concerned with the investigation including the various city of Austin departments, the Texas Parks and Wildlife Department, and the United States Fish and Wildlife Service.

PRIOR STUDIES AND REPORTS

Several prior studies and reports have been produced on the flooding problems of Shoal Creek. These are described below.

A comprehensive drainage study for the Shoal Creek drainage basin was prepared for the city of Austin in October 1974 by URS/Forrest and Cotton, Inc. This report provided 100-year flood plain delineations and water surface profiles.

A Flood Insurance Study was completed in March 1981 (Supplemental). This report provides flood plain delineations and hydraulic data for several creeks in the Austin area.

The National Weather Service, Southern Region, prepared a "Natural Disaster Survey Report, Flash Flood at Austin", dated June 1981. This report discusses the hydrologic event which occurred on 24-25 May 1981.

The Corps of Engineers prepared a Reconnaissance Report in 1981 on the flooding problems on Shoal Creek in Austin, Texas, under authority of Section 205 of the Flood Control Act of 1948, as amended. It concluded that a project could be implemented which would be economically justified and more detailed studies were recommended to determine the extent of Federal interest for construction of a flood control project.

A Draft Interim Report prepared by the Corps of Engineers in June 1987 under the Colorado River and Tributaries Authority, was circulated for public and agency review. Comments on the report resulted in the reformulation of the recommended plan in January 1988.

CHAPTER 2
STUDY AREA DESCRIPTION

This section presents a broad perspective of the study area and its existing flood problems. The material presented includes information ranging from the general terrain and climate of the study area to a summary of the employment and economic status of the area. Additional information on the study area is presented in appendix A.

NATURAL RESOURCES

LOCATION

Shoal Creek is a tributary of the Colorado River located in the west central part of the city of Austin, Texas. Austin, the capital of Texas, is located in Travis County in what is called the Texas Hill Country. This area consists of limestone hills which provide rapid runoff and subsequent high flows with very high velocities. These flows empty into the Colorado River inside the city of Austin.

Shoal Creek flows in a southerly direction through Austin for approximately 9.5 miles to its confluence with the Colorado River. The drainage area of approximately 13.2 square miles is shown in figure 2-1. With respect to major city roads, the stream lies less than 1 mile east of and parallel to State Highway Loop 1 and intersects U.S. Highway 183 in the upstream area and First Street in the downstream area.

EXISTING CHANNEL

Shoal Creek runs through a highly urbanized area. The Shoal Creek flood plain has been extensively developed except in the Pease Park area, which occupies almost 2.5 miles of the approximately 9.5 miles of defined drainage course. The remaining open area in the watershed is rapidly developing both commercially and residentially. In the upper portion of Shoal Creek, the channel is well defined and ranges from 25 to 75 feet in width and has an average depth of 8 to 10 feet. Portions of the creek above Northwest Park have been channelized previously. The creek in this area is bordered by light industry, commercial property, and residences. Retaining walls, have been constructed along the creek of various materials to protect adjacent property. Development is located very close to the creek bank. The city of Austin has made some channel improvements along approximately one mile of the channel. The work consists of intermittent stone and gabion work along the side slopes of the channel. The channel bottom typically consists of exposed or thinly covered outcrops of shale or limestone. Vegetation along the banks is primarily weedy grasses with few trees. The middle portion of the creek has several greenbelt areas and more woody vegetation. The lower portion consists primarily of the park area and is considerably wider, with widths in excess of 200 feet. The channel in this portion is generally deep, with some places up to 20 feet deep. Some commercial development is located adjacent to the creek in the downtown area. Topography of the Shoal Creek

watershed area is moderately dissected and slopes are commonly less than 5 percent except in a few local areas. The stream slope is moderate, averaging 30.5 feet per mile (0.58 percent slope).

Hancock Creek, a major tributary of Shoal Creek, has a 2 square mile drainage area and contributes significantly to the flows into Shoal Creek. It is highly developed with commercial and residential structures very close to the channel banks. The channel of Hancock Creek is also well defined with depths of approximately 6 to 10 feet and widths of 45 to 50 feet. Portions of the creek have been channelized. Along one section, the creek is diverted under a shopping center through box culverts. Vegetation along the creek consists of tall grasses and trees along the creek banks. Near the confluence with Shoal Creek limestone cliffs up to 150 feet high border the creek. Large outcroppings of rock are on the creek bottom and isolated patches of mosses and ferns are on the vertical rock walls. The stream slope is very steep averaging 57.6 feet per mile (1.09 percent slope).

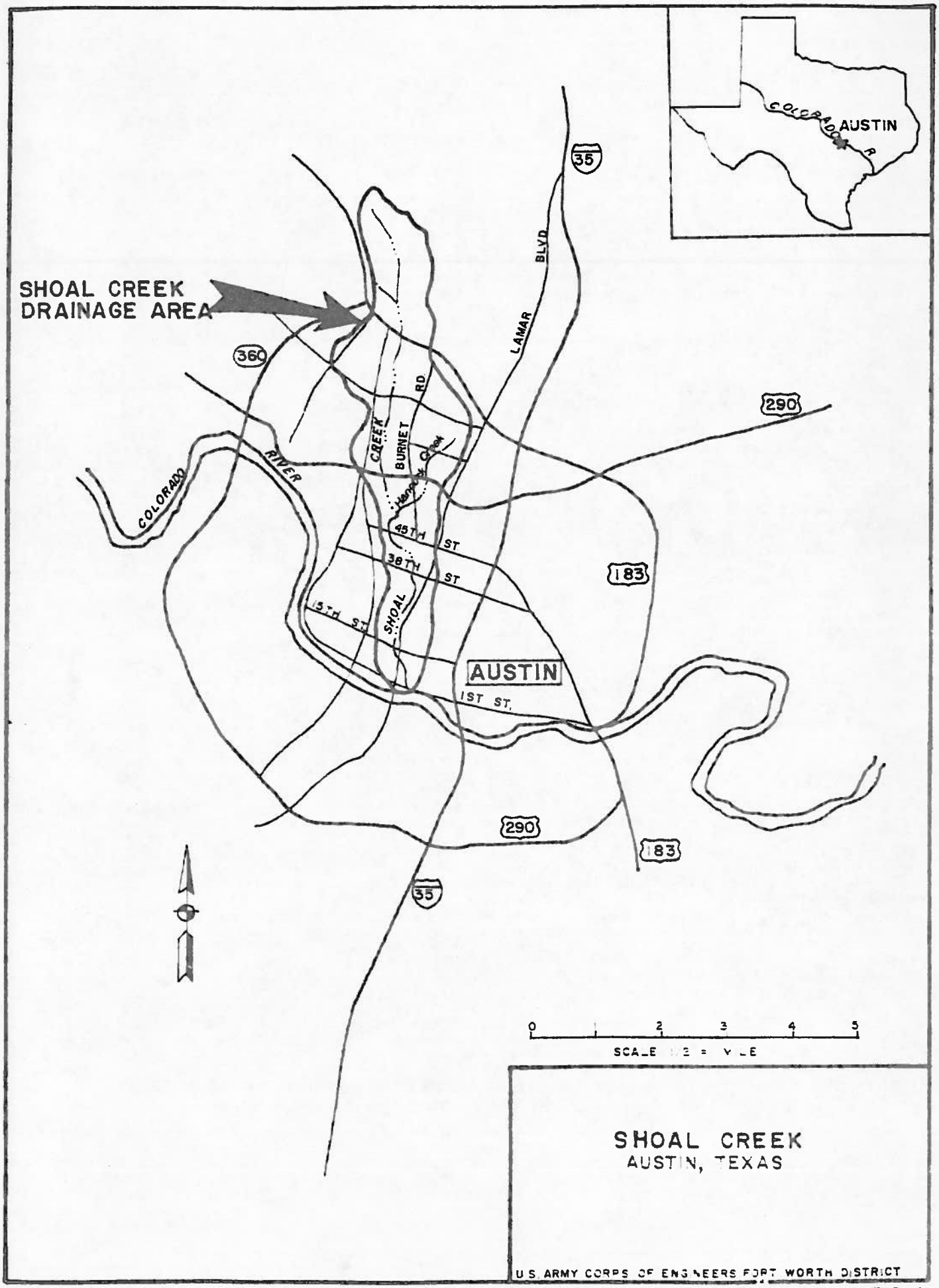
PHYSIOGRAPHY AND GEOLOGY

The Austin area is located at the boundary between two physiographic provinces; the Edwards Plateau hill country and the Coastal Plain. This region extends from the dissected margin of the Edwards Plateau (the hill country), crosses the transitional boundary of the complex Balcones fault zone, whose western limit is marked by the Mount Bonnell fault, and then crosses the rolling blackland prairie belt of the Coastal Plain to the edge of the post oak sand belt of the Coastal Plain.

Elevations of the hill country vary from 500 to more than 1,000 feet and are characterized by moderate to steep slopes. East of the city, the blackland prairie topography is mainly rolling and the ground surface elevation ranges between 500 and 800 feet.

The study area is within the drainage area of the Colorado River which flows from northwest to southeast and drains Shoal Creek. Bedrock near the Colorado River is locally mantled by flood plain and river terrace deposits. Bedrock along the tributaries is exposed or is variably covered by stream alluvium.

Shoal Creek drops about 500 feet in elevation from its headwaters to its mouth, allowing streamflows to travel rapidly. Much of the water enters into Shoal Creek quickly from the steep canyons in the northwest hills and developed areas which were designed to discharge storm waters immediately. The rocky native soils in the watershed have little storage through percolation and less relative effect during less frequent storm events. Once flows enter Shoal Creek proper, its movement downstream is impeded by gravel shoals, trees, bends, and developments which have encroached upon the earlier established water course. The high velocities which occur increase the hazard to human life, erode the natural banks, uprooting trees, and accumulate other materials which form debris dams at bridges, thereby increasing the severity of floodwater damages.



SHOAL CREEK
AUSTIN, TEXAS

U.S. ARMY CORPS OF ENGINEERS FORT WORTH DISTRICT

FIGURE 2-1

SOILS

Shoal Creek watershed is composed of several types of bedrock and alluvial soils. Bedrock soils are more predominate in middle and upper reaches of the stream and consist of dark brown to gray-brown calcareous silty and clay loams of 7- to 60-inch depth; dark brown to reddish-brown calcareous clays, clay loams, and stony clays of less than 20-inch depth; and dark gray, brown, and olive calcareous clays and clay loams of 12- to 36-inch depth. Alluvial soils predominate in the downstream reaches and consist of dark gray calcareous clay and clay loam of about 38-inch depth; brown to red-brown calcareous sandy loams, silty clay loams, and gravelly sands of 12- to 20-inch depth; and light brown to brown calcareous silt loams, silty clay loams, and sandy loams of 12- to 20-inch depth.

CLIMATOLOGY

The Austin climate is generally mild with hot summers. During the winters, occasional cold periods of short duration result from the rapid movement of cold high pressure air masses from the northwest. Snowfall is infrequent and generally insignificant from a hydrologic viewpoint.

The National Weather Service has a first order recording station at Austin, Texas. Temperatures vary in monthly averages from a low of 41 degrees F in January, to a high of 95 degrees F in July. Maximum and minimum recorded temperatures are 109 degrees F in July 1954 and -2 degrees F in January 1949, respectively. The precipitation record at Austin is almost continuous since 1856. The maximum monthly and maximum 24-hour rainfall in the Austin area was 20.78 inches in September 1921 and 19.03 inches on 9 September 1921, respectively. The annual mean rainfall is approximately 33 inches. The annual maximum and minimum rainfalls are 64.68 inches and 11.42 inches.

The city of Austin is located in a hydrologic province that places it in the path of tropical and semitropical storms which result in some of the highest rainfall rates experienced in the United States. Such storms occurred in 1915 and 1921 and in a lesser magnitude in more recent years. The U.S. Geological Survey has recorded peak flood flows from small streams in the vicinity of Austin which are some of the highest that have occurred in the United States. Storms causing these peak flood flows will occur again. In all probability, urban development in the Austin area will increase rates of flood flows, as well as total volumes of runoff.

Being located on and near the escarpment of the Balcones Fault zone, streams in metropolitan Austin are subject to extremely high rates of peak discharge. During the storm of 9-11 September 1952, Austin received less than 3 inches of rainfall; however, with a slight shift in cloud formation, Austin could have received the 21 inches which fell at Blanco, 45 miles to the southwest. The metropolitan Austin area experienced an extreme rainstorm of 19.03 inches which fell in 24 hours in 1921. The most recent severe flooding occurred in May 1981, when rainfall in excess of seven inches was reported in two hours. The rainfall centered in the Shoal Creek watershed, Waller Creek watershed, and the upper reaches of the Walnut Creek watershed. A total of 13 fatalities occurred, 5 of which

were in the Shoal Creek watershed. Minor flooding, which occurred in May 1987 did not cause any significant damages.

SURFACE WATERS

The major watercourse in the Austin area is the Colorado River, which is fed by its numerous tributaries which include Barton, Bull, Shoal, Boggy, Walnut, Waller, and Onion Creeks. The Colorado River bisects the city of Austin and is impounded in two riverine reservoirs, Lake Austin and Town Lake, within the city of Austin. Lake Austin is a popular recreational area, as well as the principal source of drinking water for the city's populace. The major tributary of Lake Austin is Bull Creek. This watershed is currently mostly undeveloped but is developing very rapidly. The Town Lake watershed consists of much of the urban core area and the lake serves as an auxiliary drinking water source and recreational area. The lake receives substantial quantities of urban stormwater runoff from primarily high-density residential and commercial areas. Both reservoirs also receive flows from adjacent springs. Shoal, Waller, and Barton Creeks are the main tributaries of Town Lake. Several major creeks enter the Colorado River below Town Lake dam, including Boggy, Walnut, and Onion Creeks. Barton Creek, along with parts of Onion Creek and its tributaries Williamson, Bear, and Slaughter Creeks, are in the Edwards aquifer recharge zone.

Since the Shoal Creek watershed is almost fully developed, it has heavy urban pollutant loadings. The pollutants are not uniformly distributed along the creek. The water quality near Northwest Park is slightly better than at 12th Street. The downstream area adjacent to the creek is highly urbanized with commercial lots. These provide impervious surfaces for pollutants to settle on before runoff carries them into the creek. Although Shoal Creek water contains a higher concentration of toxic substances than the runoff water of Lake Austin, the discharge of the creek into Town Lake does not have a significant effect on the use of the lake as a city water supply. Since there are no significant point source pollution discharges into either Lake Austin or Town Lake, stormwater runoff pollutant load is considered to be the principal contributing factor impacting the water quality of Austin area creeks and thus the lakes.

GROUND WATER

Within the Austin and adjacent outlying areas, the principal source of water for rural areas, communities, industries, and small towns are the aquifers within the basal Cretaceous Trinity Sands and the Edwards Formation. Minor aquifers are found in the low level alluvial deposits and dolomite limestone of the Glen Rose Formation. Depths to well water surface vary from about 15 to 315 feet within the Shoal Creek area. A few wells are located within and along the fringes of the watershed but are not major sources of water supply.

Many natural springs are present in the Austin area. In general, the natural springs are formed from outcrops of Edwards Formation or fractures intersecting waterbearing strata of the Edwards Formation. Some of the

natural springs in the area include Taylor (or Mormon) Springs, Mount Bonnell Springs, Powerhouse Springs, Barton Springs, and Seider Springs. Discharges from Taylor, Mount Bonnell, and Powerhouse Springs flow into Lake Austin, and discharges from Barton Springs and Seider Springs flow into Town Lake. The upstream portion of Shoal Creek watershed west of Mount Bonnell Fault acts as part of a larger Edwards recharge area for Taylor and Mount Bonnell Springs just north of Tom Miller dam (Lake Austin dam) and possibly Powerhouse Springs near the dam. Within the immediate study area, Seider Springs are located between 34th and 38th Streets along Shoal Creek with flows ranging from 0.02 cubic feet per second (cfs) to 0.32 cfs and are primarily a historical point of interest.

BIOLOGICAL SETTING

Shoal Creek lies within the Blackland Prairie vegetational region, very close to the east edge of the Edwards Plateau. Historically, this region was one of rolling hills and creek valleys with native prairie grasses dominating all but the creek banks where Texas sugarberry (hackberry), pecan, oaks, elms, cottonwoods, and other trees and shrubs formed wooded corridors.

Little farming was done along Shoal Creek as compared with the extensive agricultural activities a few miles to the east. This was due to its nearness to the rocky terrain of the Edwards Plateau and its early use as a residential area near the business district of the city. Today, most of the creek borders residential, commercial or park land with the exception of the undeveloped second growth areas near Highway 183 in the upper portion of the watershed.

Shoal Creek is not considered a wild and scenic river. No Federally listed threatened or endangered species of plants or animals appear to be resident in the study area. There are six species which are listed as endangered for Travis county. These include the Black-capped vireo, Bee Creek cave harvestman, Kretschmar cave mold beetle, Tooth cave pseudoscorpion, Tooth cave ground beetle, and Tooth cave spider. Shoal Creek is also located within the migratory route of the whooping crane (Grus americana) which is an endangered species. None of these species occur in the immediate project area and, therefore no impacts are anticipated.

COMMON BIOTA OF THE AREA

Shoal Creek is an important ecological resource within a large urban setting of Austin. Several reach areas are of particular value due to stands of natural or semi-natural vegetation, wildlife habitat, and scenic limestone cliffs. These qualities also make these sections aesthetically valuable. The park areas along the creek as well as area near the confluence of Shoal Creek with Hancock Creek are of ecological value to Austin.

Raccoons, opossums, and fox squirrels frequent the wooded sections of the creek. A multitude of birds, both residents and migrants, take advantage of the food, nesting sites, vegetational cover, and water

provided by the wooded stream environment. The undeveloped area above Highway 183 once represented good wildlife habitat for typical hill country fauna, including deer, but is now rapidly being changed by development.

Shoal Creek water quality is impacted by urban runoff and leakage from sewer lines. This is evident in some of the downstream pools by the dense algal growth, a low diversity of animal species dominated by pollution tolerant forms, and evolution of gas bubbles from nutrient rich bottoms of deeper pools. The most common fishes in most areas are mosquito fish and a few species of minnows. Sunfish are present in the deeper, more permanent sections. Bass and catfish probably also occur in the large pools such as the reservoir below Hancock Drive. Common aquatic or semi-aquatic reptiles are redear turtles (which occur in large numbers at the 10th Street "turtle pond" and in and below the reservoir below Hancock Drive), common snapping turtles, mud turtles, western ribbon snakes, and water snakes. Bullfrogs, leopard frogs, and Gulf Coast toads frequent the creek as residents and/or spawners.

HUMAN RESOURCES AND THE ECONOMY

GENERAL

An area economic study to aid in formulating a plan to address the problems and needs of the area was conducted. The area studied consists of the Austin Metropolitan Statistical Area (MSA), which contains Hays, Travis, and Williamson counties. Figure 2-2 shows a map of this area. The three-county area covers approximately 2,766 square miles in central Texas. The Shoal Creek watershed, as defined by 15 census tracts, includes approximately 13.2 square miles almost entirely within the city of Austin.

The city of Austin, the economic center of the three-county area and capital of the state of Texas, has a stable and growing economy based upon large and well established civilian government and educational employment bases. Industry and research are also strong employment factors in Austin.

POPULATION

Historically, population in the three county area has grown at a much faster rate than in the Shoal Creek watershed, increasing by 269,560 persons from 1960 to 1980 (more than 100 percent), while the watershed increased by 9,219 (20 percent) for that period. The population for the city of Austin increased by 159,345 (85 percent) for the 20-year period. The Shoal Creek Basin population is projected to increase to 74,600 persons by 2040 (a 32 percent increase from 1980) compared to 1,482,000 persons (a 176 percent increase) for the three county area. The Shoal Creek watershed is already densely populated (3,600 per square mile in 1980) and contains much of the central business district, including the capital building, and is adjacent to the main campus of the University of

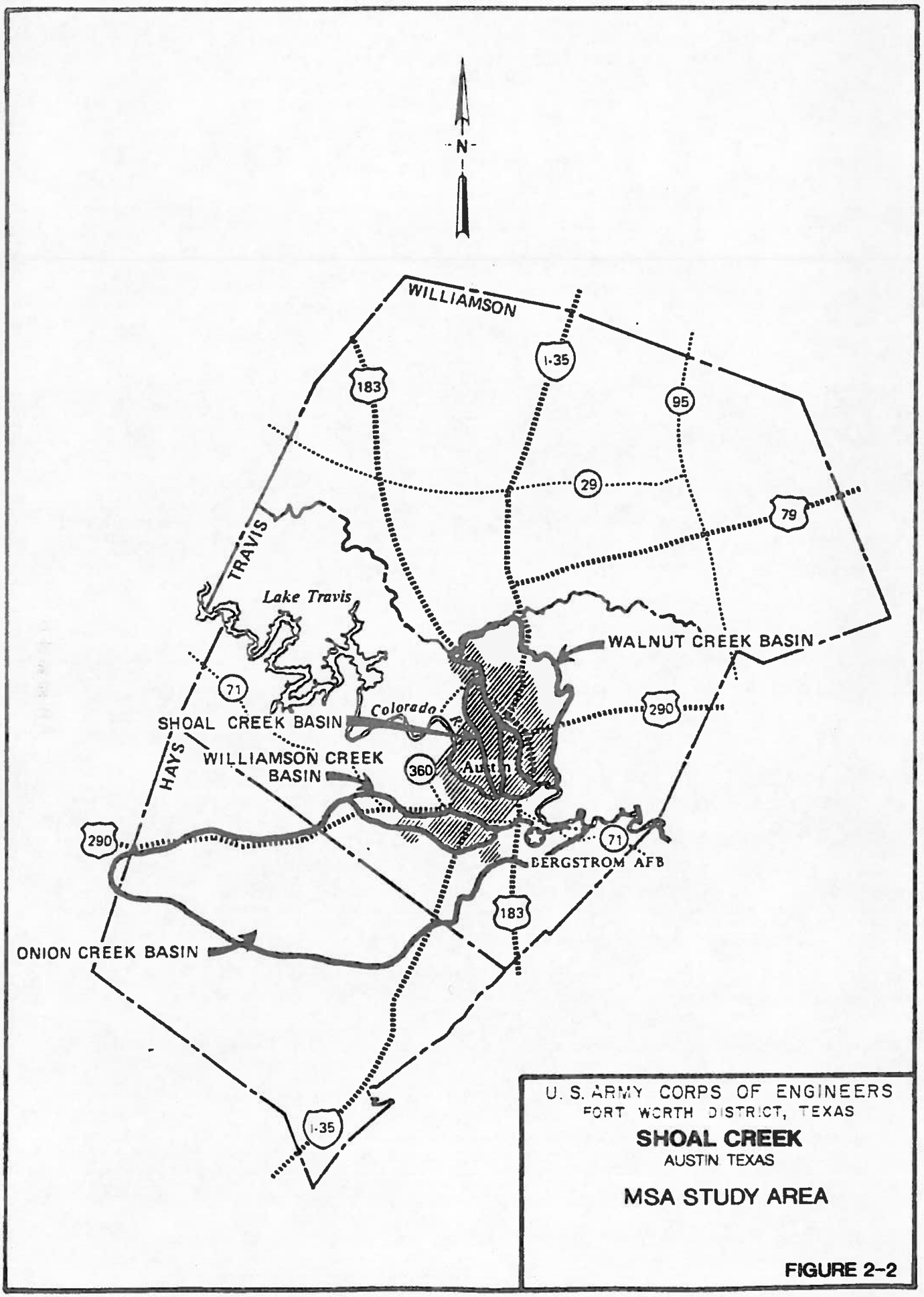

N
WILLIAMSON
TRAVIS
HAYS
Lake Travis
Colorado
Austin
WALNUT CREEK BASIN
SHOAL CREEK BASIN
WILLIAMSON CREEK BASIN
ONION CREEK BASIN
BERGSTROM AFB
I-35
183
95
29
79
71
290
360
U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS
SHOAL CREEK
AUSTIN TEXAS
MSA STUDY AREA

FIGURE 2-2

Texas. Population density of the Shoal Creek watershed in 2040 is projected to be 4,700 persons per square mile (7.4 persons per acre). A summary of population projections for the study area, the city of Austin, and the Shoal Creek watershed are shown in table 2-1. This table also provides information and projections on employment and per capita income.

EMPLOYMENT

Employment in services, trade, manufacturing, and government accounted for about 79 percent of area employment in 1980. Service industries employment was nearly 34 percent, followed by trade with nearly 20 percent, and manufacturing and government in nearly equal was the remaining 25 percent. More than 20,000 manufacturing employees were added from 1970 to 1980 but the study area percentage was still less than Texas and the U.S. in 1980. Microelectronics industries are a significant manufacturing group contributing to employment growth in Austin with 7,391 positions in electrical and electronic machinery (S.I.C. 36) in the 1980 Census. Microelectronics manufacturing is expected to benefit from the recent location of a unique high technology consortium (MCC) headquarters in Austin to perform research such as developing "fifth generation" computers to meet Japanese competition. Employment projections indicate growth of area employment in the Shoal Creek watershed from 27,295 in 1980 to 43,000 in 2040.

RECREATION DEVELOPMENT

There are a number of existing recreation resources in the Shoal Creek study area. These include Northwest District Park (31 acres adjacent to the creek between FM 2222 and Anderson Lane), Seider Springs Park (5 acres between 34th and 38th Street), Bryker Woods Greenbelt Area (7.5 acres south of 34th Street with trail linkage to Seider Springs Park), and Pease Park (approximately 80 acres between 29th and 15th Streets). Included in, and partially connecting these parks is the Shoal Creek Greenbelt with an extensively-used hike and bike trail. Also within the Shoal Creek market area are Hancock Golf Course and portions of the Colorado River/Town Lake greenbelt system. Table 2-2 shows a list of the existing recreation resources in the area.

TABLE 2-1

SUMMARY OF ECONOMIC INDICATORS
AUSTIN MSA AREA, CITY OF AUSTIN, AND SHOAL CREEK BASIN

Year	Population			Employment			Per Capita Personal Income 1/	
	MSA Area	City of Austin	Shoal Creek	MSA Area	City of Austin	Shoal Creek	MSA Area	Shoal Creek
1970	360,463	253,539	53,711	148,185	108,810	21,400	3,568 2/	4,239 2/
1980	536,674	345,890	56,419	264,961	174,773	27,295	5,157	6,193
1990	710,300	446,700	61,700	340,500	225,000	33,000	6,877	8,200
2000	896,300	561,200	66,200	435,000	280,000	38,000	8,620	10,094
2010	1,054,800	651,800	70,400	507,000	325,000	39,200	10,500	12,125
2020	1,212,400	742,300	73,600	577,000	372,000	40,400	12,789	14,493
2030	1,345,500	812,000	74,000	636,000	410,000	41,700	15,577	17,239
2040	1,482,000	883,000	74,600	700,000	451,000	43,000	17,207	19,000
FACTOR OF CHANGE FROM 1980								
1980	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	1.32	1.29	1.09	1.28	1.29	1.21	1.33	1.32
2000	1.67	1.62	1.17	1.64	1.60	1.39	1.67	1.63
2010	1.97	1.88	1.25	1.91	1.86	1.44	2.04	1.96
2020	2.26	2.15	1.30	2.18	2.13	1.48	2.48	2.34
2030	2.51	2.35	1.31	2.40	2.35	1.53	3.02	2.78
2040	2.76	2.55	1.32	2.64	2.58	1.58	3.34	3.07

1/ 1972 dollars.
2/ 1969.

SOURCE: Population, employment, and per capita personal income are from Area Economic Study, Southwestern Division, Corps of Engineers, November 1983.

TABLE 2-2

RECREATION RESOURCES

Facility/Resource	Number
Baseball field	2
Basketball court	5
Bicycling trail (mile)	10.9
Child's playground (acres)	3.8
Football fields	1
Golf holes	9
Jogging trail (mile)	2.8
Picnic tables	50
Soccer fields	3
Softball fields	6
Tennis courts	7
Walking trail (mile)	3.8

CULTURAL RESOURCES

A total of five prehistoric or historic archeological sites have been previously recorded in the area which might be affected by flood control construction. There are also three additional properties of significant historical interest. These are the Mormon Mills Springs settlement, the Seiders Oaks Texas Historic Landmark, and the historic Franz Fiset Dam located just upstream of the confluence with Hancock Creek. Other details of cultural resources are described in appendix B.

FUTURE CONDITIONS

Austin is currently participating in the Federal Flood Insurance Program and participation in this program requires that flood plain management regulations be implemented to restrict new development in the 100-year flood plain. It is anticipated that the city will continue participation in the flood insurance program, with or without Federal action, and the number of damageable structures in the 100-year flood plain will not increase or decrease in future years.

Within a city of rapid growth and development, Shoal Creek provides a natural and recreational setting to an urbanized area. Significant portions bordering the stream are greenbelt and park land areas with established hike and bike trails. Other areas adjacent and outlying are residential, commercial, and industrial development. These conditions are expected to remain relatively constant.

CHAPTER 3
PROBLEM IDENTIFICATION

FLOOD PROBLEMS

Flash flooding on Shoal Creek has occurred through the years with the most damaging storms recorded in April 1915, September 1921, November 1974, April 1975, and May 1981. In 1921, approximately 19 inches fell in a 24 hour period. The most recent devastation was caused by the May 24-25, 1981 storm. This storm produced peak rainfall rates of 4 to 6 inches per hour. The rapid rise of the floodwaters trapped families in their homes. The rate of rise was measured at 1.3 feet per minute in several parts of the city. As floodwaters flowed downstream, the water rose to a depth of 9 feet at Steck Avenue in north Austin at 11 p.m. One hour later the stage peaked at 23.2 feet deep at the 12th Street bridge. The rapid rise in water trapped numerous automobiles, some with occupants, and carried them into the main flows, blocking bridges and causing severe safety hazards. Five deaths occurred along Shoal Creek during this flood. In the upper portion of the watershed, the flood was in the neighborhood of a 100-year event, while in the downtown area it was around a 50-year event. In the May 1981 storm, 13 lives were lost in the general area and an estimated $30 million worth of damage occurred. There were 708 families affected by this storm. Although Shoal Creek was not the only stream to flood, it was the most devastated due to the density of development. The city of Austin sustained over $1 million in damages to streets and bridges alone.

HYDROLOGY AND HYDRAULICS

From the flooding sources studied in detail, standard hydrologic and hydraulic study methods were used to determine the flood data required for this study. A wide range of discharges from a 1-year flood to the standard project flood (SPF) at selected points along Shoal Creek were input into a hydraulic model which then was used to calculate resulting water surface elevations along the stream. Details of the hydrologic and hydraulic analyses are provided in appendices C and D, respectively.

The hydraulic analysis of Shoal Creek and Hancock Creek included an evaluation of the channel and overbank characteristics, such as topography, resistance to flow, and level of development. The effect of blockage of bridges was studied to evaluate its effect upon flooding. During the Memorial Day flood of 1981, many of the bridges were blocked by debris, fallen trees, and automobiles carried downstream by flood waters. This information was incorporated into the hydraulic analyses for the study.

IDENTIFYING THE FLOOD PROBLEM

Field investigations undertaken and the procedures used to identify the flood damages along Shoal Creek and Hancock Creek are described in the following paragraphs and more completely in appendix E. The area surveyed

included all flood prone properties lying within the SPF limits along 11.6 river miles of the two streams.

Reach Determinations. The affected study area was subdivided into 23 study reaches. The determination of reaches gave consideration to:

o Continuity of water surface profiles;

o Homogeneity of urban development in flood plain lands;

o Isolation of significant potential damage centers from areas of minimal or negligible damage potential.

A map of the study area and the economic reach boundaries is displayed in figure 3-1. A list of these reaches and their linear limits is shown in table 3-1.

TABLE 3-1

REACH DESCRIPTION

Reach	Station From (in feet)	Station To (in feet)	Ending Location
			SHOAL CREEK
1	0+00	47+22	West 9th Street
2	47+22	81+40	Above junction of Kingsbury and Shoal Creek
3	81+40	208+25	West 38th Street
4	208+25	251+50	West 45th Street
5	251+50	295+70	Hancock Drive
6	295+70	329+95	Northland Drive
7	329+95	349+95	White Rock Drive
8	349+95	378+08	Junction of Shoal Creek Blvd and Northpark Drive
9	378+08	402+35	Greenlawn Parkway
10	402+35	431+51	Foster Lane
11	431+51	460+64	Steck Avenue
12	460+64	482+04	Cross Creek Drive
13	482+04	497+44	Shoal Creek Blvd
14	497+44	507+69	US Hwy 183
15	507+69	520+00	Longhorn Blvd
16	481+74	507+69	US Hwy 183 and south of Cross Creek Drive (overflow)
			HANCOCK CREEK
1A	0+00	8+65	Confluence to Shoal Creek Blvd
1B	8+65	22+80	Hancock Drive
2B	22+80	30+00	Burnet Road
2A	30+00	34+75	North Loop Blvd
3	34+75	45+55	Houston Street
4	45+55	66+00	West Koenig Lane
5	66+00	109+00	Cullen Avenue

Structures Identified. A total of 922 structures were identified within the SPF flood plain limits of Shoal Creek. Of this total, 725 structures are residential dwellings with the heaviest concentrations situated in reaches 8 through 13. The second most significant concentration was commercial properties, numbering 158 structures, situated mainly in reaches 1, 2, 11, 12, and 16.

Residential structures comprise about 79 percent of the total number of flood plain properties. Typically, these consist of single story brick and wood frame structures.

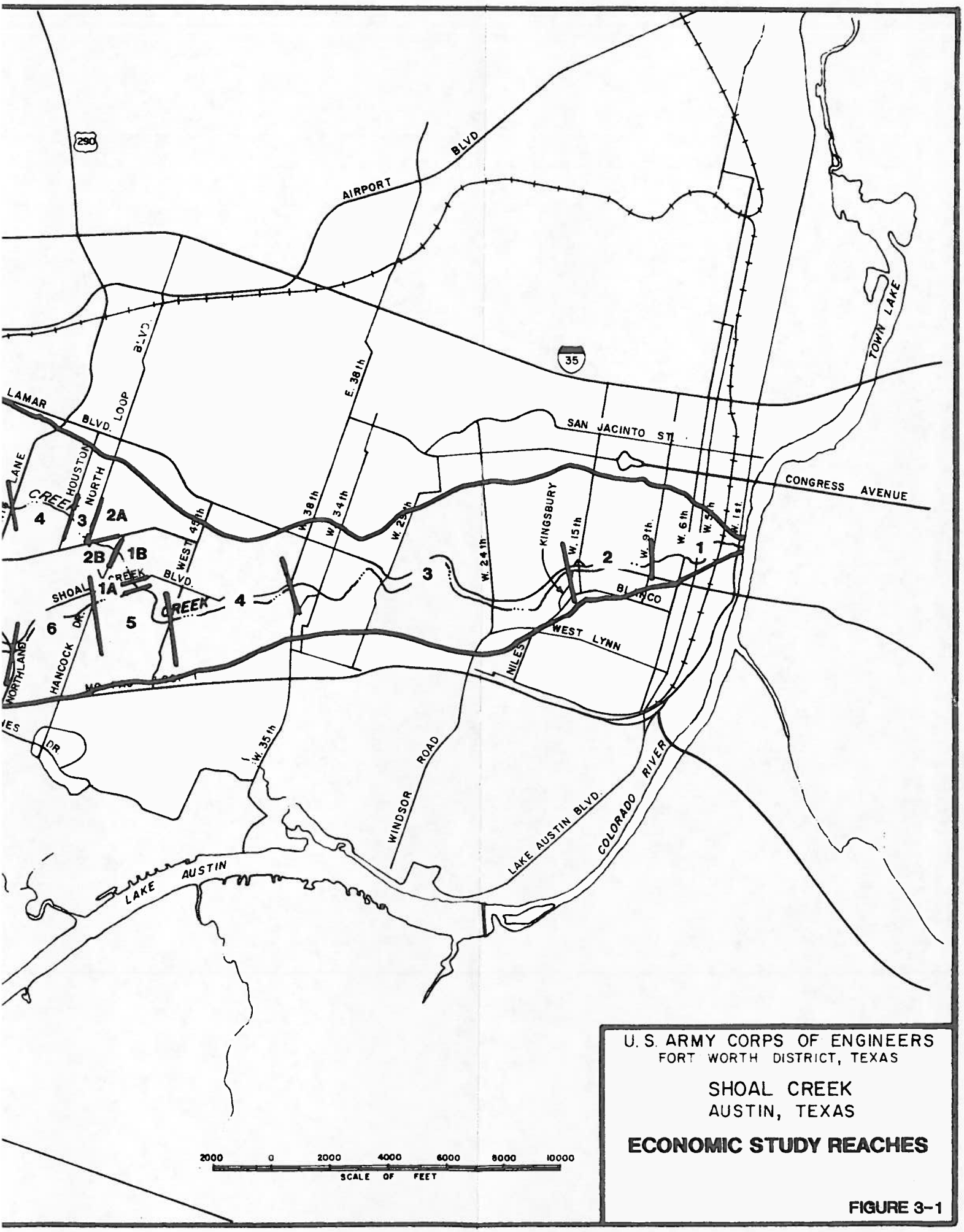
Commercial establishments make up about 17 percent of the various types of structures found in the flood plain. Included in this group are small to large retail and service establishments along with shopping centers and office buildings. There are also a total of 19 industrial, 11 transportation, 6 public and 2 communication/utility facilities located in the study area.

On Hancock Creek, the major tributary of Shoal Creek, 419 structures were counted within the SPF limits. Of these, 363 were found to be residential dwellings, 46 were commercial structures, and 10 were public and transportation-utility related facilities. The greatest concentration of residential structures is in reaches 4 and 5 with 279 structures or 77 percent. Reach 2B contains the most commercial properties with 18 facilities or about 39 percent of the total. There are two public facilities and eight transportation facilities located in the study area, which accounts for about 2 percent of the total structures. A summary of data for Shoal Creek and Hancock Creek is presented in table 3-2.

Single Occurrence Flood Losses. It is estimated that an SPF flood event in the Shoal Creek flood plain could potentially cause property damages of almost $71 million. This represents a loss of about 22 percent of the total investment along the creek. Comparatively, the 100-year event could produce losses of almost $47 million or about 14 percent of the total flood plain value. Hancock Creek would sustain losses of almost $25 million from an SPF flood event and almost $18 million from the 100-year event or 24 and 14 percent respectively of the total flood plain investment.

Average Annual Damage Calculations. Estimates of average annual damages under existing conditions were calculated through an integration process. Generally, this was accomplished by multiplication of the mean damages (derived from the stage-damage function) by the differences in the exceedance probabilities for the same stages over the range of flooding. Average annual damages were calculated for properties that could be inundated by the SPF event.

Existing Average Annual Flood Losses. Existing average annual flood loss in the Shoal Creek flood plain is estimated to be over $11.5 million, based on February 1991 prices and level of development. Of this amount, about $3.8 million or 32 percent would occur to residential properties located mainly in reaches 2 and 16, with 11 percent and 21 percent, respectively. For Hancock Creek, existing average annual damages are estimated to be over $1.8 million based on February 1991 prices and level of development. Over $1.4 million or 78 percent of the total is residential with over 68 percent of the residential damages occurring in reaches 2B, 3, and 4. A summary of the existing average annual damages, by reach, is displayed in table 3-3.



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

SHOAL CREEK
AUSTIN, TEXAS

ECONOMIC STUDY REACHES

FIGURE 3-1

TABLE 3-2
NUMBER OF STRUCTURES WITHIN SPF FLOOD PLAIN BY REACH AND TYPE
(February 1991 prices and level of development)

Reach	Residential Single Family	Residential Multi-Family	Commercial	Public	Industrial	Transportation	Communications and Utilities	Total	% of Total
SHOAL CREEK									
1	13	4	43	0	4	1	0	65	(07)
2	17	1	44	5	1	1	1	70	(07)
3	3	1	4	0	0	1	1	10	(01)
4	21	0	3	0	1	0	0	25	(03)
5	23	0	0	0	0	0	0	23	(02)
6	14	0	0	0	0	0	0	14	(01)
7	43	0	0	0	0	0	0	43	(05)
8	120	0	0	0	0	0	0	120	(13)
9	63	0	3	1	0	0	0	67	(07)
10	143	37	1	0	0	0	0	181	(19)
11	67	2	32	0	1	0	0	101	(11)
12	125	1	13	0	0	0	0	139	(15)
13	45	0	0	0	0	0	0	45	(05)
14	0	0	2	0	0	0	0	2	(0)
15	0	0	2	0	4	7	0	13	(01)
16	1	6	11	0	9	1	0	28	(03)
Subtotal	698	52	158	6	20	11	2	946	
Percent of Total	(74)	(5)	(17)	(1)	(2)	(1)	(0)*		(100)
HANCOCK CREEK									
1A	15	0	0	0	0	0	0	15	(04)
1B	35	0	4	0	0	0	0	39	(09)
2A	1	0	7	0	0	0	0	8	(02)
2B	0	2	18	1	0	0	0	21	(05)
3	17	14	8	0	0	1	0	40	(10)
4	145	8	5	0	0	7	0	165	(39)
5	126	0	4	1	0	0	0	131	(31)
Subtotal	339	24	46	2	0	8	0	419	
Percent of Total	(81)	(6)	(11)	(0)*	(0)*	(2)	(0)*		(100)
TOTAL	1,037	51	204	8	20	19	2	1,341	
Percent of Total	(77)	(4)	(15)	(1)	(2)	(1)	(0)*		(100)

* Less than one percent.

TABLE 3-3
AVERAGE ANNUAL DAMAGES BY REACH AND TYPE
(February 1991 prices)

Reach	Residential Structures	Residential Contents	Commercial	Public	Industrial	Transportation	Comm and Utilities	Public Health and Relief	Total	% of Total
	(thousands of dollars)									
					SHOAL CREEK					
1	$ 25.2	$ 18.9	$ 954.3	$ 0.0	$ 1.7	$ 19.9	$ 27.8	$ 65.0	$ 1,123.0	(9)
2	780.8	520.6	938.7	33.5	3.4	23.5	45.6	76.1	2,425.5	(20)
3	7.4	4.7	0.6	0.0	0.0	0.2	0.5	0.8	14.2	(0)*
4	10.3	8.9	7.6	0.0	6.2	0.7	1.2	2.1	37.0	(0)*
5	51.6	46.5	0.0	0.0	0.0	1.9	3.7	6.4	110.1	(1)
6	23.1	16.5	0.0	0.0	0.0	0.8	1.5	2.5	44.4	(0)*
7	29.9	24.3	0.0	0.0	0.0	1.1	2.0	3.5	60.8	(1)
8	403.0	322.6	0.0	0.0	0.0	14.6	27.7	47.2	815.1	(7)
9	9.6	5.9	0.9	0.1	0.0	0.3	0.6	0.9	18.3	(0)*
10	260.0	192.5	0.0	0.0	0.0	8.8	16.7	28.6	506.6	(4)
11	290.7	193.5	590.7	0.0	0.0	20.4	38.8	66.3	1,200.4	(10)
12	237.9	156.1	13.0	0.0	0.0	7.1	13.3	23.0	450.4	(4)
13	57.0	43.7	0.0	0.0	0.0	1.9	3.7	6.3	112.6	(1)
14	0.0	0.0	2.8	0.0	0.0	0.1	0.1	0.2	3.2	(0)*
15	0.0	0.0	101.7	0.0	2,045.4	157.1	36.5	62.5	2,403.2	(20)
16	1,406.2	823.8	31.6	0.0	115.7	40.2	67.9	116.0	2,601.4	(22)
Sub-total	$3,592.7	$2,378.5	$2,645.2	$33.6	$2,172.4	$298.6	$297.8	$507.4	$11,926.2	(100)
Percent of Total	(30)	(20)	(22)	(0)*	(18)	(3)	(3)	(4)	(100)	
					HANCOCK CREEK					
1A	$ 48.5	66.1	0.0	0.0	0.0	2.3	3.5	7.4	127.8	(7)
1B	92.5	83.7	1.8	0.0	0.0	3.6	6.7	11.5	199.8	(10)
2A	0.0	0.0	43.1	0.0	0.0	0.6	1.0	1.9	46.6	(2)
2B	180.2	121.7	149.5	10.0	0.0	8.4	15.9	27.2	512.9	(27)
3	176.8	148.8	7.3	0.0	0.0	6.6	12.6	21.5	373.6	(20)
4	273.1	163.0	3.8	0.0	0.0	11.2	14.4	24.8	490.3	(25)
5	98.8	59.8	1.0	0.0	0.0	3.0	5.8	10.0	178.4	(9)
Sub-total	$ 869.9	$ 643.1	$ 206.5	$10.0	$ 0.0	$ 35.7	$ 59.9	$104.3	$1,929.4	(100)
Percent of Total	(45)	(33)	(11)	(0)*	(0)*	(2)	(3)	(6)	(100)	
Total	$4,462.6	$3,021.6	$2,851.7	$43.6	$2,172.4	$334.3	$357.7	$611.7	$13,855.6	
Percent of Total	(32)	(22)	(21)	(0)*	(16)	(2)	(3)	(4)	(100)	

* Less than 1 percent.

RECREATION NEEDS

The recreation market area for Shoal Creek basically is comprised of that portion of the city of Austin between Interstate Highway 35 on the east and Loop 1 (MOPAC) on the west and between the Colorado River on the south and U.S. Highway 183 on the north. It includes portions of both the central business district and the University of Texas campus. According to the 1980 census, there were approximately 62,000 persons living in this area, as compared with 345,900 for the city as a whole (17.9 percent). Although not part of the most rapidly growing sectors of Austin, which are found on its periphery, particularly in the northwest and on the southwest, the central sector has experienced substantial increases in population in recent years. Most of this growth has resulted from the construction of multifamily housing units. The city's 1984 Growth Watch Report clearly indicates that housing in the area is overwhelmingly of the multifamily type. Consequently, population densities are among the highest to be found in Travis County.

This high degree of density, coupled with the demographic characteristics representative of a large student population, create a particularly great demand for recreation facilities. According to the 1985 Texas Outdoor Recreation Plan (TORP), this area can be expected to exhibit higher than average participation rates for boating, fishing, water skiing, swimming, and picnicking. In terms of actual participation rather than rate of participation, the most popular activities are walking, hiking, bicycling, jogging, and swimming. Based on population estimates and the TORP projections for recreation facility deficits, table 3-4 shows the needs identified for the Shoal Creek market area.

TABLE 3-4

EXISTING RECREATION FACILITIES AND PROJECTED NEEDS FOR THE SHOAL CREEK AREA

Facility/Resource	YEAR 1985	1990	1995
Baseball field	2	4	5
Basketball court	5	7	9
Bicycling trail (mile)	10.9	13.2	15.4
Child's playground (acres)	3.8	5.3	6.7
Football fields	1	1	1
Golf holes	9	9	9
Jogging trail (mile)	2.8	3.4	4.1
Picnic tables	50	80	123
Soccer fields	3	3	4
Softball fields	6	8	11
Tennis courts	7	11	15
Walking trail (mile)	3.8	4.7	5.6

CHAPTER 4
PLAN FORMULATION

The solution to the flood problems in the Shoal Creek watershed requires a plan which is feasible and complete within itself. The formulation of a plan to resolve the flooding and related problems and needs necessitates the exploration of all possible alternative measures, including structural and nonstructural solutions. Beneficial and adverse contributions of each alternative are evaluated against the most probable without project condition (no action alternative).

PLANNING OBJECTIVES

Planning objectives are an expression of public and professional concerns expressed about the use of water and related land resources resulting from the analysis of existing and future conditions in the study area. These planning objectives were used in guiding the development of alternative plans and their evaluation for the 1996 to 2096 period of analyses.

Legislation requires that Federal water and related land resources planning be directed to contribute to National Economic Development(NED) consistent with protecting the Nation's environment. Contribution to NED is achieved by increasing the net value of the nation's output of goods and services, expressed in monetary units. NED contributions must also consider environmental quality as pertaining to the effects of proposed changes on ecological, cultural, and aesthetic attributes of significant natural and cultural resources not measured otherwise.

Plans formulated as part of this study were evaluated based on their contribution to the Federal objective of NED and are consistent with protection of the Nation's environment. In addition to these National objectives, additional planning objectives have evolved from meetings with area residents, from contact with city, State, and Federal agencies, and from observations made in the area. They specifically identified the needs, desires, and goals of the community. The specific planning objectives for the Shoal Creek study are as follows:

o Reduce flood damages, provide better health and safety measures, reduce emergency services, and reduce the loss of jobs and/or wages caused by flooding from Shoal Creek within the city of Austin.

o Reduce potential for loss of life due to high velocity flows, isolations caused by floodwaters, and overtopping of bridges and roads along Shoal Creek.

o Preserve and protect existing environmental and aesthetically pleasing areas and maintain, as much as possible, the existing vegetation and animal habitat along Shoal Creek.

o Preserve and/or protect historically significant areas along Shoal Creek in conjunction with flood control measures.

PLANNING CONSTRAINTS

In development of flood damage reduction plans, the following constraints or limitations were considered to direct plan formulation efforts, maximize good impacts, minimize bad impacts, and to reflect restrictions of the General Investigation Program:

o Flood control projects which solve problems in one area but compound them in others, should be avoided.

o Total benefits must exceed total costs for a plan to be implemented by the Corps of Engineers.

FORMULATION AND EVALUATION CRITERIA

Plan formulation rationale used to develop effective long term solutions to the flood problems of the Shoal Creek watershed consisted of combining alternative measures into plans with consideration given to economic, social, and environmental impacts of each alternative.

Alternative plans were developed using engineering criteria taken from appropriate Corps of Engineers engineering and design manuals and regulations, related to flood control channels, outlet works, embankment, streamflow routing, backwater computation, cost estimates, etc.

TECHNICAL CRITERIA

Alternative plans must be engineeringly feasible, practicable and sound, and will be adequate to provide a project life of 100 years. Existing facilities should be utilized to the maximum extent possible. The plan should be complete within itself and not require additional future improvements other than normal replacement, and operation and maintenance.

ECONOMIC CRITERIA

The NED objective is the maximization of the economic worth of alternative plans as set forth in "Principles and Guidelines for Planning Water and Related Land Resources Implementation Studies." The NED objective is to increase the nation's output of goods and services and improve national economic efficiency. This relates to a plan's capability to prevent stream overflow by comparing the plan's economic benefits with the project cost. The amount that a project's economic benefit's exceed the project cost is defined as net benefits. In the plan formulation process, the plans that yield the greatest net benefits are the plans that fare better in meeting the NED objective.

The plan selected as the recommended plan, should provide a maximum of net benefits unless the Assistant Secretary of the Army (Civil Works) grants an exception. Such an exception may be granted for a locally preferred plan when economically justified and at the additional expense of the local sponsor.

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

o The recommended plan must be economically feasible, which dictates that the plan's flood reduction benefits must exceed the cost of the plan.

o Each separate unit or purpose of a plan must provide benefits at least equal to its costs.

o Alternative plans should be evaluated using the current Federal interest rate, a period of analysis of 100 years, and current price levels.

o Annualized costs include the cost of operation and maintenance.

Economic feasibility of a plan is displayed as a relationship of benefits-to-costs, the B/C ratio. Identified as benefits are the monetary savings or benefits due to damages prevented, reduction in the cost of emergency services, and the reduced disruption of the economy. Also included are vehicular damage reduction benefits, and reduction in insurance overhead benefits, and recreation benefits. These project benefits are subsequently annualized to represent an annual benefit applicable for the life of the project. The project cost, which includes the construction or first cost, the interest on the first cost during construction, the operation and maintenance costs, and the interest to amortize the project cost over the life of the project, are also annualized such 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 ratio of benefits to costs. To be economically feasible, a plan must have net benefits over costs, or more specifically, a benefit-to-cost ratio greater than 1.0. A 100-year period of analysis is generally applied to major flood control projects such as this. Economic evaluations made for this report utilized a 100 year period of analysis.

ENVIRONMENTAL AND SOCIAL CRITERIA

Plans formulated under Federal directives should be consistent with enhancing the existing environment by the management, conservation, preservation, creation, 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 "Principles 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:

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

o Protect quality aspects of water, land, and air resources in the watershed.

o Protect against possible loss of life and hazards to health and safety.

o Preserve and enhance social, cultural, educational, and historical values along

o Alternative plans should minimize and, if possible, avoid the destruction or disruption of community cohesion and injurious displacement of people.

PLANS CONSIDERED

Various alternative measures to satisfy the problems and needs of the Shoal Creek watershed are possible. These solutions may be divided into the two broad categories, structural and nonstructural measures. Structural measures are actions which replace or eliminate the flood damage in the problem areas by physical improvements such as channel modifications, levees, and tunnel diversions. Nonstructural measures do not reduce or eliminate floodwater levels. They are designed to manage flood plain land and development to minimize the damaging effects of floods.

STRUCTURAL MEASURES

Four basic structural measures were considered for preventing flood damages to the study area; detention reservoirs, channel improvements, levees, and tunnels. Combinations of measures were also considered where applicable.

Detention Reservoirs. Detention reservoirs are a means of controlling stream flooding by temporarily impounding floodwaters during storm events for later release when downstream conditions permit. This alternative requires the availability of an upstream impoundment site capable of providing sufficient storage.

During the course of this study, the city of Austin has constructed two detention ponds in Northwest Park. The detention ponds will collect stormwater and then release it gradually when downstream conditions permit. Recreation facilities have been incorporated into the design of these ponds and large storm events will inundate these facilities. The city has also developed three detention ponds north of US Highway 183. These ponds are designed to take care of runoff due to future development and therefore will only ease current flooding situations on a temporary

basis. Since the Shoal Creek watershed is extensively developed downstream of US Highway 183, an additional possible detention reservoir site was investigated upstream of US Highway 183. However, this site proved incapable of providing sufficient storage to reduce damages to the downstream structures along Shoal Creek. Due to the lack of a suitable site for a detention reservoir in the Shoal Creek watershed and since a significant portion of Shoal Creek would not be affected by such a structure, this alternative was not further evaluated.

Channel Improvements. Channel improvements decrease flood stage levels by improving the hydraulic carrying capacity of a stream channel. Modifications typically considered include straightening and smoothing contours of the channel thus reducing bed and bank friction, elimination of bars, and other rectification measures. The channel improvement increases the velocities and permits higher discharges through any given reach at a lower water surface elevation. An important aspect of channel improvements is the reduction of flooded areas for all flows including flows in excess of the design capacity.

Shoal Creek. Three improved channel plans were investigated for Shoal Creek: minimum improved channel, intermediate improved channel, and maximum improved channel. Channelization reaches extend the entire length of Shoal Creek from the confluence of Shoal Creek and the Colorado River to the Missouri-Pacific railroad bridge upstream of US Highway 183. Channelization was needed for the entire length of the creek to provide adequate flood protection along the creek and to control the increased flows in the channel. The channel downstream of US Highway 183 varies from grass lined trapezoidal with side slopes of 1 vertical on 3 horizontal, to concrete lined rectangular and combined grass lined 1 vertical on 3 horizontal side slopes with concrete vertical wall. The three channel plans include a 50-foot bottom width, grass lined trapezoidal channel upstream of US Highway 183 to the downstream side of the Missouri-Pacific railroad and two 11-foot conduits under US Highway 183 which bypass flow from the area upstream of US Highway 183 to the downstream channel. This size of conduit is estimated to be the largest size which can be put in the highway embankment without extensive modifications. The size of the channel upstream of US Highway 183 was based on the size of the proposed conduits and existing box culverts under the highway and the amount of capacity which would eliminate the overflow of the creek through the US Highway 183 underpass. The channel plans will require the modification of 12 bridges along Shoal Creek.

The minimum size channel has bottom widths that range from 20 feet to 90 feet. This channel provides approximately a 5-year level of protection in the lower reaches, a 25-year level in the middle portion, and a 10-year level in the upper reaches of the creek. The channel has an estimated first cost of $52,657,000 and a benefit-to-cost ratio of 1.2 to 1.0. The intermediate size channel varies in bottom width from 35 feet to 90 feet. This channel would provide about a 10-year level of protection in the lower reaches and a 25-year in the middle and upper reaches of the creek. It has an estimated first cost of $58,664,000 and a benefit-to-cost ratio is 1.2 to 1.0. The maximum size channel has bottom widths that range from 45 feet to 90 feet. The level of protection for this plan is

approximately 10-year for the lower reaches, 25-year for the middle reaches, and 50-year in the upper reaches. This channel plan has an estimated first cost of $66,777,000 and a benefit-to-cost ratio of 1.1 to 1.0. A breakdown of the costs for the three channel plans considered is shown in table 4-1 and an economic summary is contained in table 4-2.

In general, channel plans have the greatest impact on the stream environment. The complete channelization from the headwaters to the mouth of Shoal Creek would adversely impact those valued habitats along the stream even though excessive timber removal in the overbank areas and the destruction of archeological points of interest would be avoided if channelization were implemented. Excavation and channel paving may disrupt seep and spring flows which support ferns, mosses, and other unique flora along the streams. The removal of limestone cliffs and ponds would further impair the aesthetic setting of the creek. Channelization would impact park areas located along the creek. Pease Park surrounds approximately 2.5 miles of the length of the creek. Additionally there are several greenbelt areas along the creek. Channelization would have adverse impacts on the park lands. Mitigation lands would also be required with the channelization plans but costs were not included since impacts on plan selection would be relative to the various channel widths.

Hancock Creek. Channelization of Hancock Creek was also considered. The area along this tributary is extremely congested with development. A portion of the creek is diverted under a shopping center through box culverts. Due to the extensive development along the creek, a concrete U-wall channel was investigated. A grass-lined channel would not fit in the area without expensive relocations of single and multi-family residential structures and commercial buildings. Tunneling under the shopping center to make an addition to the box culverts would not be cost effective. There is one area approximately 20 feet wide between buildings in the shopping area where water could be diverted. A box culvert could be placed between these buildings. Three different sizes of channelization were considered for Hancock Creek. The channel would begin at Houston Street and extend to Burnet Road. The channel sizes investigated range from 30 to 50 feet. In the area of the shopping center, a 10-foot by 10-foot box culvert could be placed between the two buildings without the relocation or purchase of one of the buildings. For the 30-foot channel an 8-foot by 8-foot box culvert would be placed between the buildings. The 40-foot channel would include the 10-foot by 10-foot box culvert. The 50-foot channel would require the purchase of the commercial building on the south side of the shopping center. Downstream of the shopping center, the channel would be a concrete U-wall. The 30-foot channel would transition to a 40-foot U-wall for approximately 600 feet, then to a grass-lined channel downstream of Hancock Drive, before the project transitions to natural conditions. The 40-foot channel will transition to a 50-foot width downstream of the shopping center, and the 50-foot channel will transition to a 60-foot width below the shopping center. These channel plans would require the modification to bridges at Houston Street and Hancock Drive. These plans have estimated first costs ranging from $4,969,000 to $9,351,000 as shown in table 4-1. The annual benefits are shown in table 4-2. Based on the economic summary, the 40-foot channel is the most cost effective, having the greatest net benefits.

TABLE 4-1

COST SUMMARY
CHANNEL PLANS
(February 1991 Price Level)

	SHOAL CREEK Minimum Channel	Intermediate Channel	Maximum Channel
Lands and Damages	$14,925,000	$16,416,000	$19,450,000
Relocations	9,201,000	9,812,000	10,450,000
Channel	22,860,000	26,083,000	29,760,000
Engineering and Design	3,046,000	3,410,000	3,297,000
Supervision and Administration	2,625,000	2,943,000	3,297,000
Total	$52,657,000	$58,664,000	$66,777,000

	HANCOCK CREEK 30-Foot Channel	40-Foot Channel	50-Foot Channel
Lands and Damages	$ 408,000	$ 553,000	$ 1,750,000
Relocations	359,000	479,000	599,000
Channel	3,248,000	4,332,000	5,413,000
Engineering and Design	556,000	741,000	926,000
Supervision and Administration	398,000	530,000	663,000
Total	$ 4,969,000	$ 6,635,000	$ 9,351,000

TABLE 4-2

ECONOMIC SUMMARY
CHANNEL PLANS
(February 1991 Price Level)

Plan	Total First Cost	Average Annual Cost*	Average Annual Benefit	Benefit-to-Cost Ratio	Residual Damages	Net Benefits
			SHOAL CREEK			
Minimum Channel	$52,657,000	$5,275,000	$6,176,000	1.2	$7,680,000	$ 901,000
Intermediate Channel	$58,664,000	$5,878,000	$6,801,000	1.2	$7,054,000	$ 923,000
Maximum Channel	$66,777,000	$6,990,000	$7,745,000	1.1	$6,109,000	$ 755,000
			HANCOCK CREEK			
30-Foot	$ 4,969,000	$ 478,000	$ 670,000	1.4	$1,259,000	$ 192,000
40-Foot	$ 6,635,000	$ 637,000	$1,187,000	1.9	$ 742,000	$ 550,000
50-Foot	$ 9,351,000	$ 896,000	$1,401,000	1.6	$ 528,000	$ 505,000

*Includes interest during construction and annual operation and maintenance. Costs do not include mitigation measures which most likely would be required for Shoal Creek.

Channelization of Hancock Creek will not have a significant impact on fish and wildlife resources in the area. The watershed is extensively developed with commercial and residential development. The proposed increment of channelization will not extend into the section of the creek near the confluence with Shoal Creek where the area is less developed and less disturbed.

Levees. Levees were considered as a structural alternative to control the flooding problems on Shoal Creek. Levees, confine out-of-bank flows to areas along the watercourse which contain little or no damageable property. The confinement of floodwaters between levees considerably alters the characteristics of floodflows. Reduction of natural valley storage capacity can actually increase peak discharges for a given flood and consequently increase flood damages downstream. Construction of levees would require numerous relocations of structures and utilities and require expensive modifications to several roads. Lands must also be reserved for ponding areas with impounded water pumped over the levee. The associated interior drainage facilities and pumping plants are frequent problems. Levees would be required on both sides of the creek which would actually increase the water surface in the channel. Levees must be extremely high even for a low level of protection and may increase damages with catastrophic results when overtopped by flood greater than the design flood. Levees are most useful where the flood plain is appreciably wide and development is located a considerable distance from the creek.

Within the city limits of Austin there are numerous residential and commercial structures located along Shoal Creek, which limit the space available for levee construction. A levee plan would result in high relocation costs that would result in a plan which would not be feasible. The removal of sizable timber stands would also be required. Due to the adverse environmental impacts, extensive relocations, and continuing maintenance to prevent failure, this alternative was not considered feasible.

Tunnels. Considering the alignment of the creek in relation to its adjoining watershed, the Colorado River, transversing the watershed divide with diversion tunnels was considered a viable option, Diverting floodwaters through a tunnel system would minimize relocations and have the potential to provide adequate flood protection. Tunnel diversions from Shoal and Hancock Creeks into Lake Austin or Town Lake were investigated. Tunnels with various diameters were considered, with intakes at several locations along Shoal Creek. Tunnel sizes of 10-, 14-, 16-, 18.5-, and 23-foot diameters were investigated. The tunnel sizes were initially selected based on tunnel boring machines which were available. As studies progressed, it was determined that in order to optimize the flood protection while minimizing the detrimental effects on water quality, several intermediate sizes should be investigated. Intakes were considered on Shoal Creek at Northwest Park, 45th Street, 24th Street, and 19th Street. An intake on Hancock Creek was considered at North Loop Boulevard. Outlet structures were investigated on Lake Austin at Bull Creek, at Dry Creek and near Huck's Slough. Outlets on Town Lake were sited just downstream of West Lynn Street, near Orchard Street, and

near Pressler Street. When two tunnels were investigated, they were both assumed to be the same size since equipment costs for tunnels of different sizes would not be cost effective. Tunnel boring machines are many times built for a specific project. Different size tunnels would require different size machines which would result in a very high project cost. Tunnel alignments were based primarily on economic cost. Tunneling is a very expensive option; therefore, the least costly, shortest route for each alignment was chosen, taking geologic conditions into consideration.

Northwest Park Tunnel, Dry Creek Alignment. A tunnel with an intake near Northwest Park and an outlet near Dry Creek on Lake Austin was studied. Several sites in the intake area were investigated before a location just downstream of Greenlawn Parkway was chosen. The area was selected primarily because of the available land. The outlet location was chosen based on the topography of the area. Two sizes of this tunnel, which would be about 11,000 feet in length, were analyzed. The 18.5-foot and a 23-foot diameter tunnels have costs of $40,100,000 and $60,432,000, respectively. With average annual benefits of $5,231,000 for the 18.5-foot tunnel and $5,255,000 for the 23-foot tunnel, the resulting benefit-to-cost ratios are 1.3 and 0.9 to 1.0, respectively. An economic summary is provided in Table 4-3. The analyses indicated that there were still significant damages in the downstream reaches. The environmental impacts associated with this tunnel location would be centered around the effect on the water quality of Lake Austin. Lake Austin is the primary water supply for the city of Austin. The proposed outlet near Dry Creek would be located in close enough proximity to the intake for the raw water that the effect of the discharge of Shoal Creek floodwaters into the lake should be considered. The water treatment plant has no provision for an emergency shutdown. The treatment plant located on Town Lake shuts down sometimes two times a year due to flood flows on Shoal Creek. Shoal Creek carries a higher concentration of urban pollutants than Lake Austin.Since the treatment plants on Lake Austin are the primary source of water for the city, an emergency shutdown would cause water rationing. This tunnel alignment would most likely require a major modification to the water treatment plant located on the east bank of the lake. Pretreatment of the water would be required. At the least, this would involve the construction of a larger settling basin. Another impact would be the concern about the location of the outlet in an area where residential homes were located and the possibility of high velocities in the area.

Northwest Park Tunnel, Bull Creek Alignment. An alternate alignment for the Northwest Park tunnel would be from the inlet location just downstream of Greenlawn Parkway to an area on Lake Austin near the confluence of Bull Creek with the lake. Although much of the Lake Austin shoreline is developed, this outlet location would be located in an undeveloped area. It would also be located further from the water supply intake structure on the lake. The inlet location on Shoal Creek was not adjusted to minimize the tunnel length since the location minimizes impacts to the adjoining residential structures. It also controls more of the upper watershed, while utilizing the existing channel improvements which the city of Austin has made. This tunnel would be about 14,030 feet long. A 14-foot and 18.5-foot diameter sizes were estimated to have a first cost of $42,024,000 and $46,288,000. With average annual benefits

TABLE 4-3

ECONOMIC SUMMARY
TUNNEL PLANS
(February 1991 Price Level)

Plan	Tunnel Diameter	Total First Cost	Average Annual Cost 1/	Average Annual Benefits	Benefit-to-Cost Ratio	Residual Damages	Net Benefits
			(in thousands of dollars)				
Northwest Park							
Dry Creek Alignment 2/	18.5	40,100	4,001	5,231	1.3	8,625	1,230
	23	60,432	6,024	5,255	0.9	8,601	-
Bull Creek Alignment	14	42,024	4,192	5,168	1.2	8,224	976
	18.5	46,288	4,616	5,231	1.1	8,625	615
45th Street	18.5	34,193	3,571	2,425	0.7	11,431	-
	23	70,122	7,307	6,425	0.9	7,431	-
Hancock-45th Street	18.5	47,466	4,734	4,126	0.9	9,730	-
24th Street	14	26,742	2,563	2,603	1.0	11,253	40
	18.5	31,830	3,048	3,102	1.0	10,754	54
	23	37,396	3,578	3,304	0.9	10,552	-
19th Street	14	23,964	2,294	2,433	1.0	11,422	139
	16	25,422	2,432	2,533	1.0	11,322	101
	18.5	28,329	2,709	2,774	1.0	11,081	65

1/ Includes interest during construction and annual operation and maintenance. Does not include recreational development costs.

2/ Does not include pretreatment costs for the water supply intake facility which is located on Lake Austin which will be associated with this tunnel alignment.

of $5,168,000 for the 14-foot tunnel and $5,231,000 for the 18.5-foot tunnel, the benefit-to-cost ratios are 1.2 and 1.1 to 1.0, respectively.

45th Street Tunnel. Another tunnel alignment considered would have an intake on Shoal Creek just downstream of 45th Street. The outlet for this tunnel would be located on Lake Austin near Huck's Slough. This tunnel would have a length of 8,500 feet. Tunnel sizes of 18.5 and 23 feet were analyzed. The 18.5-foot tunnel has an estimated first cost of $34,193,000, benefits of $2,425,000, and a benefit-to-cost ratio of 0.7 to 1.0. The 23-foot tunnel would have a cost of $70,122,000, benefits of $6,425,000, and a benefit-to-cost ratio of 0.9 to 1.0. The impacts associated with this alignment also centered on the outlet location. The Laguna Gloria Art Museum is located near the proposed outlet. There is a prehistoric site located on this property which could be impacted if this alternative were chosen. Additionally, approximately 10 acres of the property is listed as National Register Property.

Hancock-45th Street Tunnel. A variation of the 45th Street tunnel was evaluated. This plan would have a second tunnel intake on Hancock Creek just south of North Loop Boulevard. This tunnel would have a total length of approximately 13,500 feet. The outlet would not change in location. However, an 18.5-foot diameter tunnel was not justified, having a benefit-to-cost ratio of 0.9 to 1.0. This plan also would have the same environmental concerns for the outlet location.

24th Street Tunnel. One additional tunnel was evaluated in the lower portion of the watershed. The tunnel intake would be located on Shoal Creek upstream of 24th Street. The outlet would be located on Town Lake near West Lynn Street. This tunnel would be about 7,600 feet long. Diameters of 14, 18.5, and 23 feet were studied. These tunnels ranged in cost from $26,742,000 to $37,396,000, and the benefit-to-cost ratios ranged from 1.0 to 0.9 to 1.0.

19th Street Tunnel. Another alignment for this tunnel would have an intake located near 19th Street, and an outlet near Pressler Street, which would only be about 5,100 feet long. The inlet site was chosen since it did not appear that there would be any significant additional benefits for the extra tunnel length. Tunnel diameters of 14, 16, and 18.5 feet were analyzed. The 14-foot diameter tunnel would have an estimated first cost of $23,964,000 and estimated benefits of $2,433,000 and a benefit-to-cost ratio of 1.0 to 1.0. The 16-foot tunnel would have a first cost of $25,422,000, benefits of 2,533,000, and a benefit-to-cost ratio of 1.0 to 1.0. The 18.5-foot tunnel would have a first cost of $28,329,000, benefits of $2,774,000, and a benefit-to-cost ratio of 1.0 to 1.0.

Evaluation. The alignment for the Northwest Park tunnel which would go from Northwest Park to the area near Bull Creek was selected as the best plan due to concerns about water quality in Lake Austin. This concern over water quality has been expressed by both the general public and the city of Austin staff. Since Lake Austin is the primary water supply for the city, this location would be located further from the raw water intake. Generally, Shoal Creek water carries higher concentrations of pollutants than the water in the Lake Austin watershed due to its urban

nature. The tunnel outlet location near the Bull Creek area is more acceptable from this standpoint. To further address this concern, the inlet structure for the Northwest Park tunnel was designed to allow the first 1,000 cfs of flood flows to continue down Shoal Creek.

The Hancock-45th Street tunnel outlet would have a possible adverse impact on the Laguna Gloria Art Museum area. Other sites were investigated, however a suitable alternative outlet site along Lake Austin where a tunnel could be constructed was not located. Overall, this tunnel alignment was not acceptable.

The 24th Street tunnel would provide flood protection to the downtown area, and would not present the water quality problems associated with the two other tunnels previously discussed. The outlet for this tunnel would be located on Town Lake near where Shoal Creek flows into the lake now.

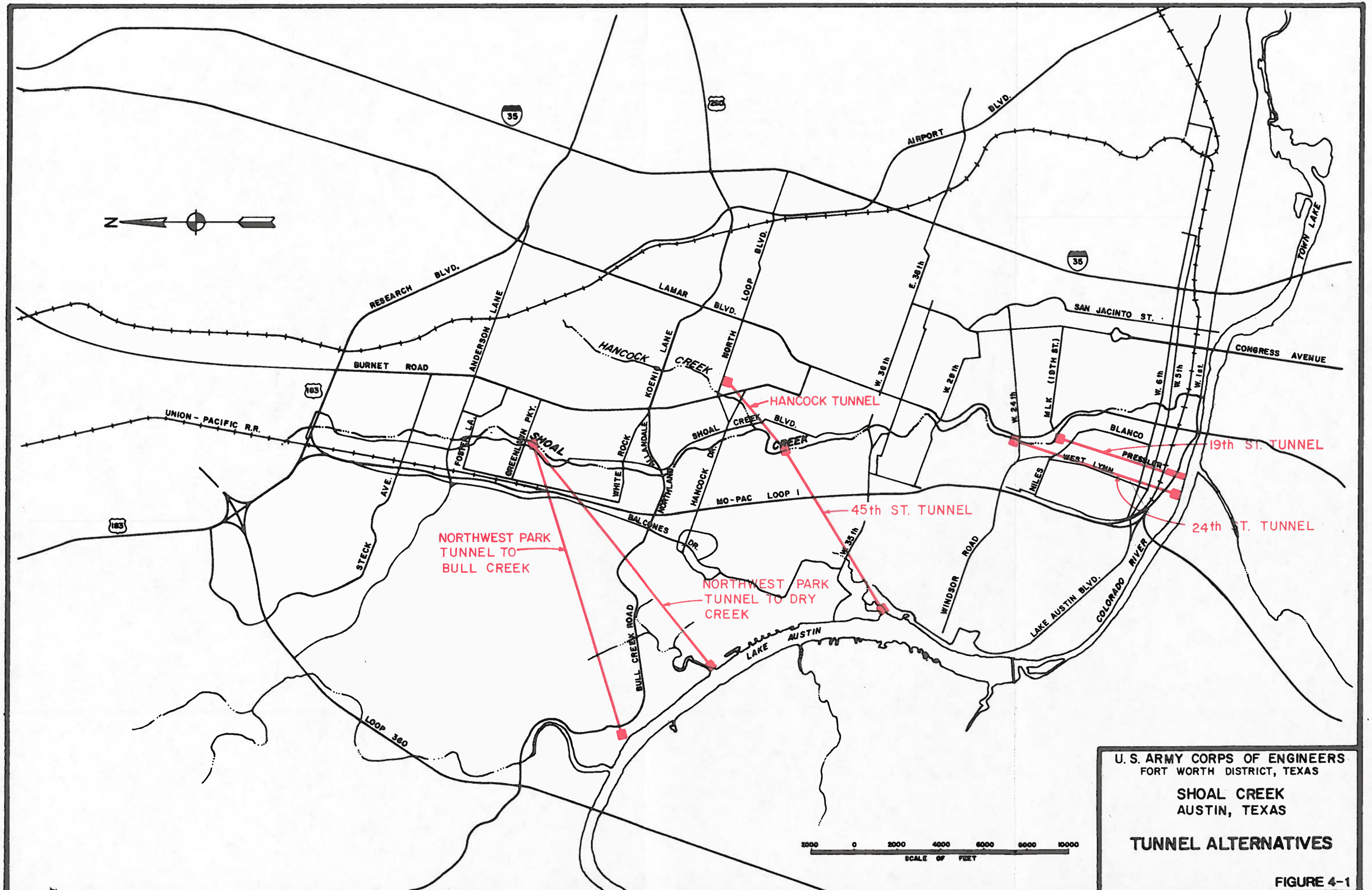
The impacts and concerns of the 19th Street tunnel would be similar to the 24th Street tunnel. No real water quality concerns exist, however there is a recreational area near the tunnel outlet which could possibly be impacted.

An economic summary of all the tunnel plans considered is provided in table 4-3. The different tunnel alignments are shown in figure 4-1. Although some of the plans were justified, hydraulic and economic analyses indicated significant portions of the damages were not eliminated; therefore, the tunnel diversion plans were not investigated as a separate alternative. They were considered in combination with channelization and in combination with one another.

Combination Plans. In order to provide a comprehensive solution to the flooding problem in the Shoal Creek watershed, "combination" plans were investigated. The plans would provide for a combination of tunnel diversion and channelization on Shoal Creek and Hancock Creek. Several combinations of plans were considered as outlined in the following paragraphs. The channelization plans on Shoal Creek extend from the railroad bridge upstream of US Highway 183 to just downstream of Foster Lane. The city has made channel improvements from that area downstream to Northwest Park. The plans are provided letter designations as shown below. The number following the letter refers to the tunnel diameter size.

Plan A - Channel, Northwest Park Tunnel. This plan includes the channelization in the upper reaches of Shoal Creek and the Northwest Park tunnel. Three sizes of tunnels were investigated for this alternative. These included a 14-, 18.5-, and 23-foot sizes. These plans ranged in cost from $59,097,000 to $72,278,000 and have estimated average annual benefits ranging from $8,037,000 to $8,274,000. All of these plans were also economically justified. An economic summary is provided in table 4-4.

Plan B - Channel, Northwest Park Tunnel, and 45th Street Tunnel. This plan was evaluated only for an 18.5-foot size tunnel. This plan has an



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

SHOAL CREEK
AUSTIN, TEXAS

TUNNEL ALTERNATIVES

FIGURE 4-1

TABLE 4-4

ECONOMIC SUMMARY
COMBINATION PLANS
(February 1991 Price Level)

	Plan	Tunnel Diameter	Total First Cost	Average Annual Cost*	Average Annual Benefits	Benefit-to-Cost Ratio	Residual Damages	Net Benefits
			(in thousands of dollars)					
A	Channel, Northwest Park Tunnel	14	59,097	5,896	8,037	1.3	5,819	2,141
		18.5	66,241	6,607	8,065	1.2	5,791	1,458
		23	72,278	7,208	8,274	1.1	5,582	1,066
B	Channel, Northwest Park Tunnel, 45th Street Tunnel	18.5	92,913	9,691	10,122	1.0	3,734	431
C	Channel, Northwest Park Tunnel, Hancock-45th Street Tunnel	10	53,019	5,543	7,503	1.4	6,353	1,960
		18.5	96,041	10,016	11,530	1.2	2,326	1,514
		23	118,119	12,312	12,728	1.0	1,128	416
D	Channel, Northwest Park Tunnel, 24th Street Tunnel	14	85,748	8,946	9,854	1.1	4,002	908
		18.5	88,371	9,219	10,356	1.1	3,500	1,137
E	Channel, Northwest Park Tunnel, 19th Street Tunnel	10	62,669	6,546	8,425	1.3	5,431	1,879
		14	74,485	7,775	9,970	1.3	3,886	2,195
		18.5	87,303	9,108	10,407	1.1	3,449	1,299
F	Channel, Northwest Park Tunnel, 19th Street Tunnel, Hancock Channel	10	70,922	7,404	9,513	1.3	4,343	2,109
		14	81,697	8,525	11,560	1.4	2,296	3,035
		18.5	93,514	9,754	11,898	1.2	1,958	2,144

* Includes interest during construction and annual operation and maintenance. Does not include recreational development costs.

estimated first cost of $92,913,000 and benefits of $10,122,000. The resulting benefit-to-cost ratio is 1.0 to 1.0.

Plan C - Channel, Northwest Park Tunnel, Hancock-45th Street Tunnel. This plan includes channelization in the upper reaches of Shoal Creek, the Northwest Park tunnel, and the Hancock-45th Street tunnel with a small amount of channelization on Hancock Creek upstream of the tunnel. The channelization in the upper portion of the watershed would be equivalent to the intermediate size channel improvement which was described under the channel improvement plans. This combination tunnel plan was evaluated for a 10-, 18.5- and 23-foot tunnel. The 10-foot diameter size of this plan did not include the second intake on Shoal Creek for the Hancock-45th Street tunnel due to the capacity of the tunnel. Flows on Hancock Creek would fill the tunnel to its capacity. All of these plans were economically justified with benefit-to-cost ratios ranging from 1.0 to 1.4 to 1.0, as shown in table 4-4.

Plan D - Channel, Northwest Park Tunnel, 24th Street Tunnel. This plan includes the intermediate channelization in the upper reaches of Shoal Creek, the Northwest Park Tunnel, and the tunnel at 24th Street. This plan was evaluated for the 14- and 18.5-foot diameter tunnel diversions. These plans have estimated first costs of $85,748,000 and $88,371,000, respectively. The 14-foot plan estimated benefits of 9,854,000 and a benefit-to-cost ratio of 1.1 to 1.0. The 18.5-foot plan has estimated benefits of $10,356,000 and a benefit-to-cost ratio of 1.1 to 1.0.

Plan E - Channel, Northwest Park Tunnel, 19th Street Tunnel. This plan is the same as the one described above, except the lower tunnel is located at 19th Street instead of 24th Street. Sizes of 10, 14, and 18.5 feet were studied. The 10-foot plan would have an estimated first cost of $62,669,000, benefits of $8,425,000, and a benefit-to-cost ratio of 1.3 to 1.0. The 14-foot size tunnel has an estimated first cost of $74,485,000, benefits of $9,970,000, and a benefit-to-cost ratio of 1.3 to 1.0. The 18.5-foot tunnel would have an estimated cost of $87,303,000, benefits of $10,407,000, and a benefit-to-cost ratio of 1.1 to 1.0.

Plan F - Channel, Northwest Park Tunnel, 19th Street Tunnel, Hancock Channel. As mentioned previously, Hancock Creek has extensive estimated average annual damages. A combination plan, containing the Northwest Park tunnel, the 19th Street tunnel, the channelization in the upper reaches of Shoal Creek and the channelization plan which was developed for Hancock Creek was evaluated for the 10-, 14-, and 18.5-foot size tunnels. These plans would have estimated costs of $70,922,000, $81,697,000 and $93,514,000 for the 10-, 14-, and 18.5-foot size, respectively. Benefits for the 10-foot tunnel would be $9,513,000 with a benefit-to-cost ratio of 1.3 to 1.0. The 14-foot tunnel would be $11,560,000 with a benefit-to-cost ratio of 1.4 to 1.0. The 18.5-foot tunnel would have estimated benefits of $11,898,000 and a benefit-to-cost ratio of 1.2 to 1.0.

Evaluation. An evaluation of these combination plans was made to determine the best plan from an economic, environmental, and social

standpoint. As mentioned previously, there are concerns for the water quality of Lake Austin. Due to these concerns, the Northwest Park tunnel which is included in the plans described above has the outlet located near Bull Creek. Again, the Hancock-45th Street tunnel is not an acceptable solution from a water quality and historical impact standpoint. Combination plans with this tunnel included as part of the project were screened from further consideration. The 24th Street and 19th Street tunnels would have similar impacts, however, the shorter length of the 19th Street does not appear to sacrifice any benefits. Overall the combination plans minimize the impacts on the fish and wildlife resources of the area, while providing comprehensive flood control to the overall watershed. A economic summary for all the combination plans considered is shown in table 4-4.

NONSTRUCTURAL MEASURES

Nonstructural measures do not attempt to reduce or eliminate floodwater levels. They are designed to manage the flood plain land and development in such a manner as to minimize the damaging effects of floods. Nonstructural measures include floodproofing, zoning, permanent evacuation, and flood warning.

Floodproofing. Floodproofing is employed primarily for the reduction or elimination of flood damages to existing structures. Possible methods of floodproofing residential and commercial structures include providing water-tight coverings for door and window openings, raising floor elevations, raising access roads and escape routes, constructing earthen levees or floodwalls around individual buildings or groups of buildings, and waterproofing walls of structures. Although more easily applied to new construction, floodproofing is also applicable where flooding is of short duration, low velocity, infrequent, and of shallow depths. Floodproofing is also appropriate in locations where structural flood protection is not feasible or where collective action is not possible. Floodproofing techniques would require major modifications to the existing structures.

Floodproofing could be accomplished by either raising floor elevations or installing flood shields on existing structures. Installing flood shields is generally not as effective as raising the structures because there are more occasions for error. They must be expeditiously moved into place and, if there is not enough warning time or if the residents could not be contacted, considerable damage could be sustained. Floodproofing by raising structures in place is definitely more practical than utilizing flood shields but there are still some problems, due primarily to required extensive modifications. Since the warning time to install flood shields is short and the depths of flooding are not shallow, benefits for this alternative would be minimal, thus, this alternative was not considered further.

Zoning. Zoning regulations or land use restrictions are regulatory measures adopted by local governments to control future development in floodprone areas. Zoning insures the safekeeping of property for the public health and welfare and the best use of available land. The

regulations adopted by the city of Austin restrict development in the flood plain by requiring that the first floor elevations exceed the 100-year flood level by a minimum of 1 foot. Such regulations avoid compounding of flood damage problems but offer no relief to existing developments. A zoning alternative, therefore, is of limited effectiveness where a high damage potential already exists, therefore, no further evaluation of this alternative was considered.

Permanent Evacuation. Permanent evacuation of developed flood plain areas could be adopted to eliminate the flood damage potential to whatever frequency of flooding might be decided, i.e., 5-year, 50-year, 100-year, SPF. However, this alternative does not provide any protection to structures above the design frequency. This would require the acquisition of all privately owned lands, dwellings, and related improvements by purchase. The dwellings and structures would be removed, the population relocated to flood-free housing, and the land converted to nature areas or other uses consistent with periodic flooding. Benefits for this alternative are derived from the value of the new use of the land, the reduction in damages to public property, the reduction in emergency costs, and administration of disaster relief, and reduction in flood insurance subsidy. In order to screen this alternative, average annual costs were compared to average annual damages prevented. This would be overstating the benefits, however it would indicate if any degree of this type of alternative might prove feasible. For this analysis, only residential structures were considered to be removed. For the 5-year flood plain, approximately 157 residential structures would be evacuated, however this would only remove about six percent of the development within the SPF flood plain, therefore significant damages would still occur. For the evacuation of the 5-year flood plain, average annual costs are estimated to be $997,000 and average annual damages prevented are $600,000, resulting in a benefit-to-cost ratio of 0.6 to 1.0. This plan could cause severe social disruption. Evacuation of the 1-year flood plain was also considered, since it would have less of a social impact. This would involve the removal of 24 structures. However, this plan was not considered further since it was estimated to have a benefit-to-cost ratio of 0.8 to 1.0, based on the damages prevented. Therefore, permanent evacuation was not considered further.

Flood Warning. Flood warning systems are available through cooperation with the National Weather Service of the U.S. Department of Commerce. Flood forecasting and temporary evacuation 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. Flood forecasting can be accomplished by remote sensors to detect water rise or through the more elaborate means of flood forecasting center using rainfall data, computer modeling, and extensive meteorological data. Notification of impending flooding can be by radio, noise maker or individual notification. While this alternative does not materially reduce damages, it does prevent loss of life in areas subject to flash or fast rising floods. Flood forecasting can create a sense of nonconcern or false security where warnings are issued and minor flooding occurs or no damage is caused. Flood forecasting for short drainage basins is almost ineffective. Forecasting for larger basins and

watercourses can be utilized effectively. These measures normally serve to reduce the hazards to life and damage to portable personal property. They may do so at a continuing cost to the community-at-large to maintain an emergency assistance capability.

Recently, the city installed rain and stream gages to more accurately predict when and where flooding is likely to occur so that flood plain residents can be better advised; eliminating damages. The system is computerized. When heavy rains occur in the Austin area, a computer at the city emergency office can telephone four city engineers at home and tell them in a synthesized voice which creeks are rising and how much rain has accumulated at points throughout the city. The computer can also set off an alarm in the engineer's home computers. With the short warning time, little damageable property can be saved. It will help prevent loss of life; however, flood damages will still occur. Therefore any additional flood forecasting efforts would not present a complete solution to the flooding problems and thus this alternative was not considered further.

THE NO ACTION ALTERNATIVE

The most probable future for the study area in the absence of a structural or nonstructural plan to reduce flood damages is designated as "the no action" alternative. The beneficial and adverse contributions of all structural and nonstructural plans considered for the Shoal Creek watershed were evaluated against the most probable without project condition ("no action" alternative).

Existing developments in the flood plain of Shoal Creek will probably remain fairly stable. The existing flood threat, however, tends to discourage repairs and improvements by homeowners and investors.

The city of Austin is currently participating in the Federal Flood Insurance Program. Participation in the regular program requires that flood plain management regulations be implemented to restrict new development in the 100-year flood plain. It is anticipated that the city will continue participation in the flood insurance program and that the number of damageable structures in the 100-year flood plain will not increase in future years.

There is intense urban development already within the flood plain; therefore, very little land is available for growth. There is available flood free land elsewhere in the city. Most of the undeveloped land is in the upper portion of the watershed. The detention ponds upstream of US Highway 183 will take care of any increase in discharges due to this development.

Future development within the 100-year flood plain is prevented by city ordinances; however, development can still take place between the 100-year and SPF flood limits.

A large percentage of the land use in the study area consists of residential activities. While it is likely that the land use in the study

area will continue to be used primarily for residential activities, the existing flood threat tends to discourage repairs and improvements by homeowners and investors. The recurring flood damages are expected to continue to cause slow deterioration of the homes in the flood plain and it is possible that more loss of life could occur.

Average annual damages would be about $13,856,000 for the study area. There would also be cost involved for emergency flood fighting, temporary disruption of traffic and utilities, loss of production and employment, disruption of schools, potential disease from stagnated floodwaters, and the potential for loss of life. Future flood damages could be partially mitigated by the city of Austin and flood plain residents through continued enforcement of zoning regulations, participation in the Federally subsidized flood insurance program, individual floodproofing of structures where affordable, and flood warnings.

IDENTIFICATION OF THE NED PLAN

Detailed studies were performed on the alternative plans discussed in the previous sections. Those plans were the minimum, intermediate, and maximum channel improvements on Shoal Creek and a channelization plan on Hancock Creek. Six different combination plans were considered for various sizes of tunnel diversions. Plan F14, the 14-foot combination tunnel/channel plan which includes the Northwest Park tunnel and the 19th Street tunnel, along with channelization on Shoal and Hancock Creeks was designated as the NED plan. Analysis of the plans revealed that the channelization plans would provide some degree of flood protection but would result in significant losses to fish and wildlife resources along Shoal Creek. The channelization plans would also involve excessive timber removal and the destruction of archeological points of interest. The combination plans, on the other hand, provide a significant degree of flood protection while causing only minimal losses to the stream environment. Table 4-5 shows the alternative plans, along with the average annual costs, benefits, net benefits, and the benefit-to-cost ratio. Additional information on the assessment of the alternative plans is provided in the System of Accounts in table 4-6.

Based on the assessment as discussed, Plan F14 was identified as the NED plan. All of the combination plans minimize the losses to the environment and provide flood protection to the area, however, this plan optimizes net benefits while providing a high degree of flood protection.

SELECTION OF A PLAN

A solution to the flooding problems in the Shoal Creek Watershed requires formulation and evaluation of alternative plans which could resolve the flooding problems. The following criteria were used in the evaluation and selection of a plan. The Recommended Plan should maximize the NED objective unless circumstances can be shown which indicate a need

to deviate from this criteria. The selected plan also needs to be economically justified and provide a reasonable degree of protection. The selected plan should also avoid detrimental environmental and social effects. The selection of a recommended plan depends upon careful consideration of engineering, economic, social, and environmental factors.

While Plan F14 is the "best" plan from an economic standpoint, the city of Austin was presented the opportunity to review and make a decision on the recommendations. After weighing all of the data provided, the city has made the decision to implement only a portion of the NED plan. The city has indicated they would like to proceed with the Hancock Creek Channel portion of the project. The 40-foot channel was selected as the optimum size project based on net benefits. Since this is known as a "buy-down" from the NED plan, the same cost sharing rules apply as long as the smaller plan is still feasible. The Corps does not object to the deviation from the NED plan, and therefore, the locally preferred plan was selected as the Recommended Plan.

TABLE 4-5

ECONOMIC SUMMARY
STRUCTURAL PLANS
(February 1991 Price Level)

Plan	Tunnel Diameter	Total First Cost	Average Annual Cost*	Average Annual Benefits	Benefit-to-Cost Ratio	Residual Damages	Net Benefits
			(in thousands of dollars)				
Shoal Channel							
Minimum Channel		$52,657	$5,275	$6,176	1.2	$7,680	$ 901
Intermediate Channel		58,664	5,878	6,801	1.2	7,054	923
Maximum Channel		66,777	6,990	7,745	1.1	6,109	755
Hancock Channel							
30-Foot		4,969	478	670	1.4	1,259	192
40-Foot		6,635	637	1,187	1.9	742	550
50-Foot		9,351	896	1,401	1.6	528	505
Plan A							
Channel, Northwest Park Tunnel	14	59,097	5,896	8,037	1.3	5,819	2,141
	18.5	66,241	6,607	8,065	1.2	5,791	1,458
	23	72,278	7,208	8,274	1.1	5,582	1,066
Plan B							
Channel, Northwest Park Tunnel, 45th Street Tunnel	18.5	92,913	9,691	10,122	1.0	3,734	431
Plan C							
Channel, Northwest Park Tunnel, Hancock-45th Street Tunnel	10	53,019	5,543	7,503	1.4	6,353	1,960
	18.5	96,041	10,016	11,530	1.2	2,326	1,514
	23	118,119	12,312	12,728	1.0	1,128	416
Plan D							
Channel, Northwest Park Tunnel, 24th Street Tunnel	14	85,748	8,946	9,854	1.1	4,002	908
	18.5	88,371	9,219	10,356	1.1	3,500	1,137
Plan E							
Channel, Northwest Park Tunnel, 19th Street Tunnel	10	62,669	6,546	8,425	1.3	5,431	1,879
	14	74,485	7,775	9,970	1.3	3,886	2,195
	18.5	87,303	9,108	10,407	1.1	3,449	1,299
Plan F							
Channel, Northwest Park Tunnel, 19th Street Tunnel, Hancock Channel	10	70,922	7,404	9,513	1.3	4,343	2,109
	14	81,697	8,525	11,560	1.4	2,296	3,035
	18.5	93,514	9,754	11,898	1.2	1,958	2,144

* Includes interest during construction and annual operation and maintenance. Does not include recreational development costs.

TABLE 4-6
SYSTEM OF ACCOUNTS

Accounts	Most Probable Future Without Project	Minimum Channel	Intermediate Channel	Maximum Channel	Plan A	Plan B	Plan C	Plan D	Plan E	Plan F
Shoal Creek Austin, Texas April 1990 Prices	Conditions as they exist today with continued participation of the city in the Flood Insurance Program.	Combination grass-lined and concrete channel plan with 20- to 90-foot bottom widths from station 6+00 to the MOPAC RR at station 525+00.	Combination grass-lined and concrete channel plan with 35- to 90-foot bottom widths from station 6+00 to the MOPAC RR at station 525+00.	Combination grass-lined and concrete channel plan with 45- to 90-foot bottom widths from station 6+00 to the MOPAC RR at station 525+00.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and a tunnel diversion from NW Park to Lake Austin near Bull Creek Creek. 14-, 18.5- and 23-ft tunnels.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and tunnel diversions from NW Park to Lake Austin near Bull Creek and 45th St. to Huck's Slough. 18.5-ft tunnel.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and tunnel diversions from NW Park to Lake Austin near Bull Creek and from North Loop on Hancock with a second intake near 45th to Huck's Slough. 10- 18.5- and 23-ft tunnels.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and tunnel diversions from NW Park to Lake Austin near Bull Creek Creek and from 24th St. to Town Lake. 14- and 18.5-ft tunnels.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and tunnel diversions from NW Park to Lake Austin near Bull Creek and from 19th St. to Town Lake. 14- and 18.5-ft tunnels.	A 35- to 50-ft bottom width channel from Foster Lane to the MOPAC RR and tunnel diversions from NW Park to Lake Austin near Bull Creek and from 19th St. to Town Lake and channeliztion on Hancock Creek. 10-, 14- and 18.5-ft tunnels.
A. National Economic Development (NED)										
1. Beneficial Impacts Average Annual Benefits		$6,176,000	$6,801,000	$7,745,000	$8,037,000 8,065,000 8,274,000	$10,122,000	$ 7,503,000 11,530,000 12,728,000	$ 9,854,000 10,356,000	$ 8,425,000 9,970,000 10,407,000	$ 9,513,000 11,560,000 11,898,000
2. Adverse Impacts Average Annual Project Costs		5,368,000	5,982,000	7,131,000	6,000,000 6,724,000 7,335,000	9,887,000	5,654,000 10,219,000 12,561,000	9,127,000 9,405,000	6,649,000 7,932,000 9,292,000	7,554,000 8,735,000 9,950,000
3. Net Benefits		807,000	819,000	614,000	2,036,000 1,431,000 939,000	235,000	1,849,000 1,311,000 166,000	727,000 951,000	1,747,000 2,038,000 1,115,000	1,959,000 2,825,000 1,947,000
4. Benefit-to-Cost Ratio		1.2	1.1	1.1	1.3 1.2 1.1	1.0	1.3 1.1 1.0	1.1 1.1	1.3 1.3 1.2	1.1 1.3 1.2
B. Environmental Quality										
1. Beneficial Impacts a. Suburban Open Space	No effect.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.	Purchase of project right-of-way will provide public access to open area along channel.
b. Natural Resources Ecologically Significant Areas	No effects.	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects

TABLE 4-6
SYSTEM OF ACCOUNTS (CON'T)

Fauna and Habitat	No effects.	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects
c.Pollution	No foreseeable effects.	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects	Minimal effects
d.Water Quality	No effect without some unforeseen action by local interests.	No effects	No effects	No effects	No effects	No effects	No effects	No effects	No effects	No effects
e.Archeological/ Historical Resources	No known significant effects.	Any data discovered would be preserved.	Any data discovered would be preserved.	Any data discovered would be preserved.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.	Any data discovered would be preserved. Downstream sites would be less adversely affected from floodflows.
2. Adverse Impacts										
a.Biological Resources										
Riparian Wildlife Habitat	No effect.	Loss of 154 acres of habitat. Additional 21 acres reduced to 90 percent value.	Loss of 176 acres of habitat. Additional 19 acres reduced to percent value.	Loss of 195 acres of habitat.	Loss of 20 acres of habitat. Remaining land will retain its value.	Loss of 26 acres of habitat. Remaining land will retain its value.	Loss of 37 acres of habitat. Remaining land will retain its value.	Loss of 20 acres of habitat. Remaining land will retain its value.	Loss of 20 acres of habitat. Remaining land will retain its value.	Loss of 26 acres of habitat. Remaining land will retain its value.
Aquatic and Semiaquatic Habitat	No effect.	Significant loss of spawning beds and emergent flora.	Significant loss of spawning beds and emergent flora.	Significant loss of spawning beds and emergent flora.	Slight loss with reduction of flushing flows and limited channelization.	Slight loss with reduction of flushing flows and limited channelization.	Slight loss with reduction of flushing flows and limited channelization.	Slight loss with reduction of flushing flows and limited channelization.	Slight loss with reduction of flushing flows and limited channelization.	Slight loss with reduction of flushing flows and limited channelization.
Terrestrial, Avian, and Aquatic Habitat	No effect.	Significant decrease in diversity due to channelization.	Significant decrease in diversity due to channelization.	Significant decrease in diversity due to channelization.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek.	Minimal decrease in fauna diversity due to limited channelization and reduction of floodflows along Shoal Creek. Minimal loss of habitat along Hancock Creek.
b.Manmade Resources	Continued flood damages to manmade structures.	$7,680,000 in residual damages.	$7,054,000 in residual damages.	$6,109,000 in residual damages.	$5.5 to 5.8 mil.in residual damages.	$3,734,000 in residual damages.	$1.1 to 6.3 mil. in residual damages.	$3.5 to 4.0 mil. in residual damages.	$3.4 to 5.4 mil. in residual damages.	$1.9 to 4.3 mil. in residual damages.
c.Water Quality	No effects.	Temporary turbidity during construction.	Temporary turbidity during construction.	Temporary turbidity during construction.	Temporary turbidity during construction. Slight increase in nonpoint source pollutants in Lake Austin.	Temporary turbidity during construction. Moderate increase in nonpoint source pollutants in Lake Austin.	Temporary tuburity during construction. Moderate increase in nonpoint source pollutants in Lake Austin.	Temporary tuburity during construction. Slight increase in nonpoint source pollutants in Lake Austin. Minimal effects on Town Lake.	Temporary tuburity during construction. Slight increase in nonpoint source pollutants in Lake Austin. Minimal effects on Town Lake.	Temporary tuburity during construction. Slight increase in nonpoint source pollutants in Lake Austin. Minimal effects on Town Lake.

TABLE 4-6
SYSTEM OF ACCOUNTS (CON'T)

d.Hydrological Characteristics	No effects.	Minimal effect.	Minimal effect.	Minimal effect.	Moderate effects with transfer of water to another watershed.	Moderate effects with transfer of water to another watershed.	Moderate effects with transfer of water to another watershed.	Moderate effects with transfer of water to another watershed.	Moderate effects with transfer of water to another watershed.	Moderate effects with transfer of water to another watershed.
e.Air Pollution	No effects.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.	Slight short term increase during construction.
f.Archeological/ Historical Resources	No known significant effects.	Some reduction along Shoal Creek.	Some reduction along Shoal Creek.	Some reduction along Shoal Creek.	No significant effects.	No significant effects.	No significant effects.	No significant effects.	No significant effects.	No significant effects.
g.Land Resources	No effects.	154 acres of riparian, commercial, and residential developments converted to channel land.	174 acres of riparian, commercial, and residential developments converted to channel land.	195 acres of riparian, commercial, and residential developments converted to channel land.	20 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.	26 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.	37 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.	20 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.	20 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.	26 acres of riparian, commercial, and residential developments converted to channel land and tunnel portals.
h.Irreversible Effects	None.	9.8 miles of natural stream committed to channel.	9.8 miles of natural stream committed to channel.	9.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.	1.8 miles of natural stream committed to channel.
C. Other Social Effects										
Beneficial and Adverse Impacts										
a.Aesthetic Values	Expected to remain essentially the same.	Significant removal of rock cliffs and forested areas.	Significant removal of rock cliffs and forested areas.	Significant removal of rock cliffs and forested areas.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.	Minimal effects. Few features of Shoal Creek are impacted. Slight visual impacts on Lake Austin.
b.Desirable Community Growth	Community will grow at present rate.	No significant impact.	No significant impact.	No significant impact.	No significant impact.	No significant impact.	No significant impact.	No significant impact.	No significant impact.	No significant impact.
c.Population	Will continue at present growth rate.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.
d.Community Cohesion	Gap between flood plain residents and rest of city will widen.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.	Beneficial effect.
e.Tax Revenues	Tax base for flood plain will decrease slightly.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.	Would remove some land from tax rolls; will be partially offset by increase in property values.
f.Property Values	Will remain constant inside flood plain.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.	Value of property in protected area will increase. Maintenance costs will increase.
g.Public Services	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.

TABLE 4-6
SYSTEM OF ACCOUNTS (CON'T)

h.Public Facilities	No effect.	Park facilities may be affected in several areas.	Park facilities may be affected in several areas.	Park facilities may be affected in several areas.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.	Minimal impact in park area near tunnel inlets. Lake operations will need to be adjusted some.
i.Employment/ Labor Force	Will continue proportionate to population growth.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.	Short term increase during construction for beneficial impact.
j.Displacement Population	Will not change due to Flood Insurance Program.	None.	None.	None.	None.	None.	None.	None.	None.	None.
k.Business and Industrial Activity	Slight adverse effect.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.	Minimal beneficial impact.
l.Noise	No effect.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.	Short term increase during construction.
m.Desirable Regional Growth	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.
D. Regional Growth										
Beneficial and Adverse Impacts	Economic growth trends will continue at about the same rate.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.	No effect.

CHAPTER 5
THE RECOMMENDED PLAN

PLAN DESCRIPTION

The recommended plan as shown in figure 5-1, is Hancock Creek channel portion of the NED plan. On Hancock Creek, 1,500 feet of concrete U-wall channel will begin just upstream of Houston Street and extend downstream to Burnet Road. A box culvert will divert some water around the shopping center and will flow back into Hancock Creek below the shopping center. The U-wall channel will continue from the shopping center to below Hancock Drive and then transition into a grass-lined channel ending about 700 feet downstream of Hancock Drive. The total length of improved channel on Hancock Creek is 3,200 feet.

DESIGN

The Hancock Creek channel improvements will be approximately 3,200 feet long and begin just upstream of Houston Street where the natural channel will transition to a grass-lined channel with a 40 foot wide bottom and 1 vertical on 3 horizontal side slopes. The Houston Street bridge will be replaced by a new multiple box culvert of four 8-foot high by 10-foot wide concrete boxes. Downstream of Houston Street the channel will be a 40-foot concrete U-wall channel which is approximately 10 feet deep and will extend downstream to Burnet Road. The existing box culverts under the shopping center and Burnet Road will remain. A new 10-foot by 10-foot box culvert will be routed on the south side of the shopping center between two buildings. This box culvert will tie back into the creek just downstream of the culverts which run under the shopping center. A concrete U-wall channel with a 50-foot bottom width will extend from the shopping center to approximately 120 feet below Hancock Drive. The existing multiple box culvert at Hancock Drive consisting of three 8-foot by 8-foot boxes will remain. Three new 8-foot by 8-foot boxes will be constructed adjacent to and on the same grade as existing boxes. The channel will have a depth of 8 to 9 feet. The channel will then transition to a 25-foot bottom width grass-lined channel with 1 vertical on 3 horizontal side slopes. The channel will transition back to the natural channel 700 feet downstream of Hancock Drive.

RELOCATIONS

The improvements to Hancock Creek will require bridge relocations at Hancock Drive, North Loop Boulevard, and Houston Street. The existing multiple box culvert at Burnet Road which goes under the shopping center will remain in place. The proposed box culvert at the shopping center will be constructed between the shopping center buildings and adjacent commercial buildings and under Burnet Road.

Utility relocations on Hancock Creek will include water, sewer, gas, electric, and telephone lines. Sewer alterations will include approximately 1,560 linear feet of 24-inch diameter pipe, and 3,120 linear feet of 8-inch diameter pipe.

DISPOSAL

The city of Austin has identified a couple of disposal sites for the material excavated from the project. These sites are located near southeast Austin. One site is a gravel pit which would be more than sufficient for the material. This site is located near the intersection of FM 973 and Harold Green Road. Another site is located in the same general vicinity. The area is open land, located about 1.5 miles west of U.S. Highway 183 and just south of the Colorado River near a mobile home park. There are several other gravel pits in southeast Austin and west of Austin which may be available for use as disposal sites when construction begins. The haul distance to the sites which the city has identified averages approximately 10 miles. No problems are anticipated with disposal of the excavated waste materials. Approximately 5 acres will be needed for disposal of the material.

REAL ESTATE

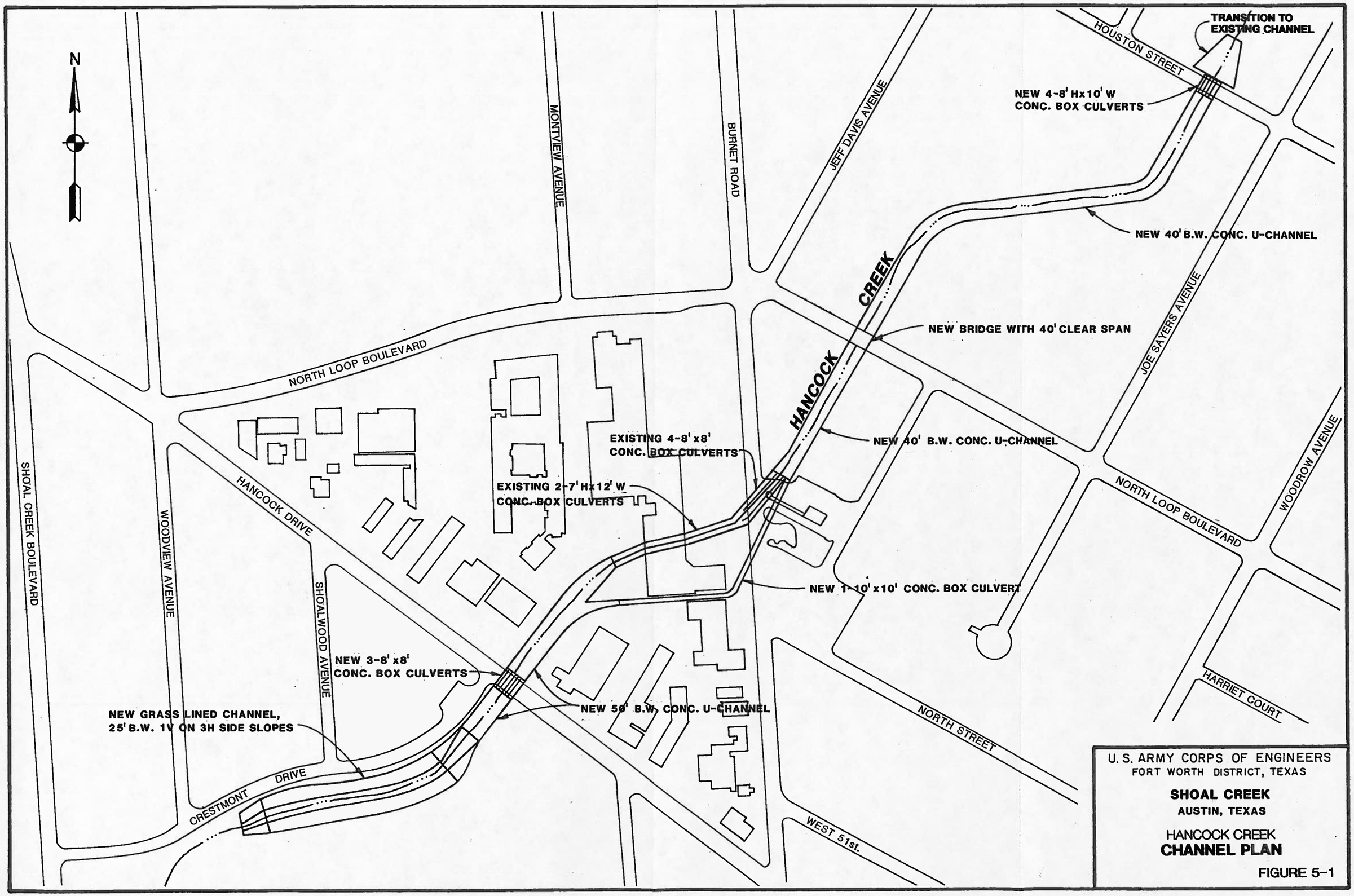
Property along the proposed Hancock Creek channel improvement will extend from just above Houston Street to approximately 700 feet downstream of Hancock Drive. A channel easement on approximately 3.1 acres will be acquired for the construction of the channel. An estimated 0.7 acres of temporary work area easement will be required for construction of the project. More details of the real estate required are shown in the Real Estate Appendix. No permanent residential or commercial structures would be relocated or purchased. The total cost of real estate acquisitions is estimated to be $552,900. The real estate costs are based on a gross appraisal prepared in September 1989. Detailed real estate information for this project is contained in the appendix H.

CONSTRUCTION

Project construction would involve removal of an estimated 40,500 cubic yards of material. During construction, protective measures cited in the environmental guidelines for the civil works program of the Corps of Engineers would be enforced for such things as erosion, dust control, and proper debris disposal methods. Construction of the Hancock Creek Channel is expected to take approximately two years.

OPERATION AND MAINTENANCE

The Federal Government and the city of Austin will enter into a local cooperation agreement under which the city would accept the project after completion and insure maintenance and operation in accordance with Federal regulations. The major items of operation and maintenance of the completed project include: mowing the grassed portion of the channel, periodic cleanout of the concrete portion of the channel and drainage systems, and repair of erosion damage to the slopes of the channel. Subsequent to completion of this project, an operation and maintenance manual would be prepared by the Fort Worth District and furnished to the city of Austin.


N
TRANSITION TO EXISTING CHANNEL
HOUSTON STREET
NEW 4-8' H x 10' W CONC. BOX CULVERTS
MONTVIEW AVENUE
BURNET ROAD
JEFF DAVIS AVENUE
NEW 40' B.W. CONC. U-CHANNEL
HANCOCK CREEK
NEW BRIDGE WITH 40' CLEAR SPAN
JOE SAYERS AVENUE
NORTH LOOP BOULEVARD
NEW 40' B.W. CONC. U-CHANNEL
EXISTING 4-8' x 8' CONC. BOX CULVERTS
EXISTING 2-7' H x 12' W CONC. BOX CULVERTS
HANCOCK DRIVE
SHOAL CREEK BOULEVARD
WOODVIEW AVENUE
SHOALWOOD AVENUE
NORTH LOOP BOULEVARD
WOODROW AVENUE
NEW 1-10' x 10' CONC. BOX CULVERT
NEW 3-8' x 8' CONC. BOX CULVERTS
NEW 50' B.W. CONC. U-CHANNEL
NEW GRASS LINED CHANNEL, 25' B.W. 1V ON 3H SIDE SLOPES
HARRIET COURT
NORTH STREET
CRESTMONT DRIVE
WEST 51st.
U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
HANCOCK CREEK
CHANNEL PLAN
FIGURE 5-1

PLAN ACCOMPLISHMENTS

The major benefits that will result from the plan are reduction of existing flood damages to structures along Hancock Creek. Average annual benefits of $1,187,400 are estimated for the existing improvements in the area. The plan has residual damages of $742,000. The level of protection of the plan varies throughout the length of the creek. Table 5-1 provides an estimation of the level of protection of the project by reach. There are no induced damages downstream of the recommended plan.

TABLE 5-1

LEVEL OF PROTECTION AND PERCENTAGE DAMAGE REDUCTION RECOMMENDED PLAN

HANCOCK CREEK

Reach	Existing Level	Modified Level	Percent Damage Reduction
1A	2	10	10
1B	1	2	15
2A	5	100	95
2B	5	50	92
3	10	100	97
4	2	5	53
5	2	2	6
Hancock Overall Range	1 to 10	2 to 100	62

EFFECT OF THE PLAN ON THE ENVIRONMENT

The selected plan will minimize the adverse environmental impacts. The channelized portions are limited to extensively developed areas along Hancock Creek which are relatively low in wooded habitat. Therefore, the channelization of the recommended plan will have no significant effects on wildlife. No significant impacts to water quality and aquatic life are expected to occur as a result of the recommended plan.

ECONOMICS OF THE SELECTED PLAN

This section of the report presents a detailed cost estimate for the selected plan and the flood control benefit analysis. The costs determined and the benefits assigned to the plan evaluated encompass only those that are tangible or quantifiable. In calculating both costs and

benefits, prices were set at the February 1991 level and a 50-year period of analysis (1996-2046) at 8-3/4 percent interest rate.

COSTS

First Cost. The economic cost of the selected plan described includes estimates for lands and damages, construction, engineering and design, supervision and administration, and contingencies. Construction cost data for the channel were developed using material, equipment, and labor costs typical for work of this nature in the Austin vicinity in February 1991. Table 5-2 gives the detailed first cost estimate for the selected plan.

TABLE 5-2
COST ESTIMATE
RECOMMENDED PLAN
(February 1991 price level)

Cost Acct No.	Item	Amount
01	LANDS AND DAMAGES	$ 442,300
	Contingencies 25%±	110,600
	TOTAL LANDS AND DAMAGES	$ 552,900
02	RELOCATIONS	
	Roads and bridges	190,300
	Utilities	195,200
	Subtotal	$ 385,500
	Contingencies 25%±	93,700
	TOTAL RELOCATIONS	$ 479,200
09	CHANNEL	3,485,900
	Contingencies 25%±	844,700
	TOTAL CHANNEL	$ 4,330,600
18	CULTURAL RESOURCES	800
	Contingencies 25 %±	200
	TOTAL CULTURAL RESOURCES	$ 1,000
30	ENGINEERING AND DESIGN	741,000
31	SUPERVISION AND ADMINISTRATION	530,000
	TOTAL PROJECT FIRST COST	$ 6,634,700

Annual Charges. To be comparable with benefit estimates, the project first cost was converted to an equivalent average annual basis. To that, estimates of average operation and maintenance costs and annual equivalent charges for replacement of features not expected to function properly over

the entire period of analysis were added. For the purpose of determining the total investment, construction was assumed to be phased and a two year construction period was assumed. Table 5-3 provides a breakdown of annual charges for the Recommended Plan.

TABLE 5-3

HANCOCK CREEK CHANNEL PLAN
AVERAGE ANNUAL CHARGES

Total First Cost	$ 6,634,700
Interest During Construction	589,000
Total Investment	$ 7,223,700
Interest and Amortization (50 years at 8-3/4%)	641,800
Annual operation, maintenance and replacements	5,000
Total Annual Charges	$ 646,800

BENEFITS

This section presents information on the economic evaluations performed to calculate the benefits accruing to the selected plan of improvement for Hancock Creek. The benefits assignable to this plan encompass only those that are tangible and quantifiable.

Existing Inundation Reduction Benefits. Average annual benefits were determined by subtracting residual flood losses from the without project annual flood losses. Since future hydraulics are not expected to change, benefits to existing development are expected to remain constant over time. Reaches 2B, 3, and 4 of Hancock Creek have the greatest amount with $1,090,100, or about 92 percent of the total. Table 5-4 displays a summary of the existing flood reduction benefits for the Recommended Plan, by reach.

TABLE 5-4

EXISTING AVERAGE ANNUAL DAMAGES, RESIDUAL DAMAGES AND BENEFITS
(February 1991 Prices and Level of Development)

Reach	Annual Damages	Residual Damages	Annual Benefits
	(in thousands of dollars)		
	HANCOCK CREEK		
1A	127.8	114.4	13.4
1B	199.8	170.7	29.1
2A	46.6	1.0	45.6
2B	512.9	43.5	469.4
3	373.6	11.9	361.7
4	490.3	231.3	259.0
5	178.4	169.2	9.2
Subtotal	$ 1,929.4	$ 742.0	$ 1,187.4

Benefit Summary. The benefits attributable to the recommended plan were calculated based on a 50-year project life (1996-2046) and an 8-3/4 percent interest rate. Subsequent to the completion of the economic analysis, consideration was given to other potential types of flood control benefits which would accrue to the recommended improvements. Two additional benefit categories identified were vehicular damage reduction and insurance cost reduction benefits. Estimates of the project benefits which would accrue to this plan are presented in table 5-5.

TABLE 5-5

SUMMARY OF AVERAGE ANNUAL FLOOD CONTROL BENEFITS
(February 1991 price and level of development)

Category	Benefits
Inundation Reduction	$ 1,187,400
Vehicular Damage Reduction	39,300
Insurance Overhead Reduction	3,000
Total	$ 1,229,700

ECONOMIC JUSTIFICATION

The normal measure of economic feasibility is the benefit-to-cost ratio being greater than or equal to 1.0. The average annual cost for the Recommended Plan is $646,800. Average annual benefits are estimated to be $1,229,700. This results in a benefit-to-cost ratio of 1.9 to 1.0. Additional details of the Recommended Plan are included in the appendix E.

DIVISION OF PLAN RESPONSIBILITIES

COST APPORTIONMENT

Sharing of costs between Federal and non-Federal interests for the project is based on standard requirements established as Federal policy in Public Law 99-662. Under this law, non-Federal interests would be required to furnish all lands, easements, and rights-of-way, including all relocations of bridges and utilities. Non-Federal interests would be required to furnish a cash contribution equal to 5 percent of the total flood control project cost and would also be responsible for operating and maintaining the project features after construction. Additionally, if the non-Federal share of project costs is less than 25 percent of the flood control costs an additional cash payment will be required. The non-Federal interests will be required to provide a minimum of 25 percent of the flood control cost and 50 percent of the separable recreation costs. The Federal Government would be responsible for all remaining flood control construction cost. Table 5-6 shows the apportionment of the first cost and annual operation, maintenance, and replacement (OM&R) costs between Federal and non-Federal interests, in accordance with the policies outlined above.

NON-FEDERAL RESPONSIBILITIES

Prior to commencement of construction, local interests must agree to meet the requirements for non-Federal responsibilities as outlined below and in future legal documents.

a. Provide a cash contribution equal to 5 percent of the total flood control project costs;

b. Provide without cost to the United States, all lands, easements, and rights-of-way,including borrow and dredged material disposal areas, necessary for construction and maintenance and operation of the project;

c. Perform all relocations and alterations of buildings, utilities, highways, railroads, bridges (other than railroad bridges), sewers, and related and special facilities determined to be necessary for construction and maintenance of the project;

d. Provide an additional cash payment when the sum of items (a) and (b) is less than 25 percent of the flood control project costs (if the sum of items (a) and (b) should exceed 50 percent of total flood control project costs, local contributions in excess of 50 percent will be reimbursed by the Federal Government;

e. Maintain and operate the project after completion and provide any needed replacements or rehabilitations of any of its components;

TABLE 5-6
COST APPORTIONMENT
(February 1991 price level)

	First Costs Flood Control		Annual Operation, Maintenance, and Replacements	
	Federal	Non-Federal	Federal	Non-Federal
Lands		$ 552,900		
Relocations		479,200		
Channel	$4,330,600			$ 5,000
Cultural Resources	1,000			
Engineering and Design	703,000	38,000		
Supervision and Administration	490,000	40,000		
Subtotal	$ 5,524,600	$1,110,100	$ 0	$ 5,000
Cost Sharing Reallocation 1/	- 548,900	+ 548,900		
Total	$ 4,975,700	$ 1,659,000	$ 0	$ 5,000

1/ Non-Federal interests are required to provide a minimum of 25 percent of the total flood control cost. Five percent must be a cash contribution.

f. Hold and save the United States free from damages due to construction and subsequent operation and maintenance of the project, except damages due to the fault or negligence of the United States or its contractors;

g. Make cash contribution for project costs assigned to project features other than flood control, including 50 percent of the cost of recreation development;

h. Prevent encroachment which could interfere with proper functioning of the flood control project;

i. For any project for local flood protection, participate in and comply with applicable Federal flood plain management and flood insurance programs (i.e. the National Flood Insurance Program), pursuant to Section 402, Public Law 99-662;

j. Publicize, at least annually, the fact that the project will not provide protection from the occurrence of storms greater than the project design flood;

k. Comply with the provisions of the "Uniform Relocation Assistance and real Acquisition Policies Act of 1970," Public Law 91-646, approved 2 January 1971, and with the requirement of Section 221, Public Law 91-611, approved 31 December 1970, as amended.

l. Comply with the requirement of Section 2 of Public Law 89-72 with respect to the recreational features of the project.

m. Comply with Title VI of the Civil Rights Act of 1964 (Public Law 88-352).

PLAN IMPLEMENTATION

The plan of improvement recommended in this report will be subject to a series of reviews and legislative processes before it can be completed as a Federal project. The following steps are involved in the review and implementation process:

- o Review of Feasibility Report by the Division Engineer, Southwestern Division, Corps of Engineers.
- o Release of Division Engineer's Notice.
- o Review by states and agencies.
- o Public Meeting and finalization of Feasibility Report.
- o Review of the Report by the Washington Level Review Center.
- o Preparation of the Board of Engineers for Rivers and Harbors (BERH) Report.

- o Preparation of the Chief of Engineers Report.
- o Approval of Report by the Assistant Secretary of the Army for Civil Works.
- o Report to Congress.
- o Project Authorization.
- o Preparation and Approval of Design Memorandum.
- o Preparation of construction plans and specifications.
- o Review of plans and specifications by the Division Engineer.
- o Review of the Local Cooperation (Cost Sharing) Agreement by the Chief of Engineers.
- o Approval of the project for construction by the Assistant Secretary of the Army for Civil Works.
- o Consummation of the Local Cooperation Agreement between the Corps and the city of Austin.
- o Local sponsor acquires the necessary real estate for construction and maintenance of the project.
- o Receipt of the Sponsor's 5 percent cash contribution prior to initiation of construction.
- o Chief of Engineers allocates construction funds.
- o Award construction contract.

Formal agreement of local cooperation (LCA) will be required before construction of the project can begin. Budgeting for work items is accomplished two years in advance. All funding is subject to appropriations by Congress.

PUBLIC AND AGENCY COORDINATION

Close coordination has been maintained throughout this study with the city of Austin officials, as well as interested State and Federal agencies and the general public. On August 12, 1987, a public meeting was held in Austin to discuss the results of the June 1987, Draft Interim Report. At this meeting opposition to the plan which was presented was expressed. Alternatives to this plan were developed and are presented in this report. On October 27, 1987, alternative plans were presented to the Austin city council. These plans were referred to the city staff for recommendation.

Another public meeting was held on July 18,1990. The city has reviewed the report and elected to proceed with implementation of the Hancock Creek portion of the NED plan which was presented.

Coordination has been maintained with the U.S. Fish and Wildlife Service throughout this study. Their Coordination Act Report is included in the environmental assessment.

CHAPTER 6
DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter briefly describes the results of the feasibility level investigations to identify significant water resources needs and problems of the Shoal Creek watershed, and to present a plan which would be responsive to them.

DISCUSSIONS

This feasibility study for the Shoal Creek watershed is an interim report being conducted under the Colorado River Basinwide study authority. Studies were initiated at the request of the city of Austin, in fiscal year 1983. The primary problem identified in studies was the need for flood control. Flash flooding on Shoal Creek has occurred through the years with the most recent damaging storms occurring in November 1974, April 1975, and May 1981. The most devastating storm was the May 1981 storm. Although other watersheds in Austin were affected, Shoal Creek was one of the worst hit areas. Five deaths occurred along the creek during this flood. The SPF flood plain of Shoal Creek has 922 structures and Hancock Creek, a major tributary to Shoal Creek has 419 structures in the SPF flood plain.

A range of structural and nonstructural plans were investigated to provide protection to the area. Of the nonstructural plans investigated, no economically feasibly plans were identified. Structural plans considered included channelization of the creek,, tunnel diversions, and combination tunnel/channel plans. Of these plans, Plan F14 was identified as the NED plan. This plan consists of two 14-foot diameter tunnel diversions and channelization on both Shoal and Hancock Creeks. After review, the city elected to implement only a portion of the NED plan. The city of Austin has decided to buy-down to the Hancock Creek portion of the NED plan. This segment of the plan was therefore designated as the Recommended Plan. The economics of the Recommended Plan are discussed in the following section.

CONCLUSIONS

The Recommended Plan as described in this report represents the city's desire to help alleviate flooding problems along Hancock Creek. The Recommended Plan would capture 62 percent of the average annual flood damages estimated to occur for existing conditions within the Hancock Creek study area.

This plan consists of 3,200 feet of 40- to 50-foot bottom width channel along Hancock Creek. The first cost of the Recommended Plan at February 1991 price levels, is estimated at $6,634,700. Under current guidelines, the city of Austin would be responsible for $1,659,000 and the Federal Government would pay $4,975,700. The city of Austin would be

responsible for all operation, maintenance, and replacement costs, estimated to be $5,000 annually. The city of Austin has the authority and capability to finance the construction requirements through bonds. Funds to operate and maintain the project following construction can be provided through the city's annual operating budget.

The total annual charges for the Recommended Plan, including operation, maintenance, and replacement costs, is $646,800. Average annual benefits for the Recommended Plan are $1,229,700. These include inundation reduction benefits, vehicular benefits, and reduction in insurance overhead benefits. The resulting benefit-to-cost ratio is 1.9 to 1.0.

Although the city of Austin was not in a financial or authoritative position which will allow officials to commit to financing of the NED plan for Shoal Creek, the Hancock Creek project is significantly smaller. The funding problems appear to be short term, and the city is optimistic that funding would be available for the smaller Hancock Creek project.

RECOMMENDATIONS

The Recommended Plan as described in this report is recommended for construction. This plan, is the Hancock Creek channel plan and includes channel improvements for flood control. The estimated first cost of this plan is $6,634,700.

I recommend that the Hancock Creek channel plan selected herein for flood damage reduction along Hancock Creek be authorized for implementation as a Federal project, with such modifications as in the discretion of the Chief of Engineers may be advisable, at a first cost to the United States presently estimated at $4,975,700.

Prior to commencement of construction, the local sponsor, the city of Austin, must agree to meet the requirements for non-Federal responsibilities as outlined in the report and in future legal documents. The local sponsor has demonstrated that they have the authority and the financial capability to provide all non-Federal requirements for construction, operation, and maintenance of the project.

John A. Mills
Colonel, Corps of Engineers
District Engineer

R 11/91

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect programs 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.

RECORD OF ENVIRONMENTAL CONSIDERATION

SHOAL CREEK
AUSTIN, TEXAS

An Environmental Assessment (EA) was prepared in 1990 which addressed the impacts of the construction of the 14-foot combination tunnel/channel plan. This plan consisted of the following improvements on Shoal Creek and Hancock Creek, the major tributary: approximately 1,200 feet of 50-foot bottom width grass-lined channel improvement on Shoal Creek from the MOPAC railroad bridge to U.S. Highway 183; two 11-foot conduits under U.S. Highway 183; 10,200 feet of 30- to 50-foot bottom width, grass-lined channel improvement from U.S. Highway 183 to Greenlawn Parkway; a 14-foot diameter tunnel diversion with an intake downstream of Greenlawn Parkway and an outfall at Lake Austin near Bull Creek; a 14-foot diameter diversion tunnel with an intake on Shoal Creek near 19th Street and an outlet close to Town Lake near Pressler Street; 750 feet of grass-lined channel from the tunnel outlet to Town Lake. Recreational development will be provided along the channelization in the upper reaches of Shoal Creek. The plan also included a 40- to 50-foot bottom width concrete channel along 3,200 feet of Hancock Creek from just upstream of Houston Street to 700 feet downstream of Hancock Drive.

The EA evaluated the impacts of the alternatives considered, including channelization and the combination channel/tunnel plans. The Recommended Plan was discussed and evaluated in the EA. A Finding of No Significant Impact (FONSI) which was circulated for public and agency review in July 1990, concluded that the impacts of the 14-foot combination channel/tunnel plan would not be significant. The FONSI was signed in August 1991.

The city of Austin has reviewed the 14-foot combination channel/tunnel plan and, after weighing all of the data provided, made the decision to implement only a portion of the this plan. They have indicated they would like to proceed with the Hancock Creek portion of the project. This segment of the project is significantly smaller than the plan evaluated in the EA. This plan has an estimated first cost of $6,634,700. Under current guidelines, the city of Austin would be responsible for $1,659,000 and the Federal Government would pay $4,975,700. The city of Austin would be responsible for all operation, maintenance, and replacement costs, estimated to be $5,000 annually. The total annual charges for the Recommended Plan, including operation, maintenance, and replacement costs, is $646,800. Average annual benefits for the Recommended Plan are $1,229,700. These include inundation reduction benefits, vehicular benefits, and reduction in insurance overhead benefits. The resulting benefit-to-cost ratio is 1.9 to 1.0.

The selected plan will minimize the adverse environmental impacts. The channelized portions are limited to extensively developed areas

along Hancock Creek which are relatively low in wooded habitat. Therefore, the channelization of the recommended plan will have no significant effects on wildlife. No significant impacts to water quality and aquatic life are expected to occur as a result of the recommended plan.

It has been determined that the proposed action is not a significant change from the plan evaluated in the EA and FONSI. The FONSI, which was signed in August 1991, adequately addresses the impacts of the down scaled recommended plan, and therefore the impacts are insignificant.

3 Oct 91
Date

John A. Mills
Colonel, Corps of Engineers
District Engineer

FINDING OF NO SIGNIFICANT IMPACT

LOCAL FLOOD PROTECTION PROJECT
(FLOOD CONTROL ACT OF 1936, AS AMENDED)
SHOAL CREEK, AUSTIN, TEXAS

Shoal Creek in Austin, Texas, is a tributary to the Colorado River. At the request of the city of Austin, the Fort Worth District prepared initial documentation under the authority of Section 205 of the Flood Control Act of 1948, as amended. Further study was accomplished through the Corps' General Investigation Program under the specific Congressional authorization for the Colorado River and Tributaries, as mandated in the Flood Control Act of 1936, Section 6; Committee on Commerce Resolution of 1936; River and Harbor Act of 1937, Section 4; and River and Harbor Act of 1945, Section 6. Under this Congressional direction, the U.S. Army Corps of Engineers formulated and evaluated an array of potential solutions to local flooding problems.

Preliminary alternatives that were eliminated from consideration included levees, detention reservoirs, flood proofing, and permanent evacuation. Plans considered in detail included a "no action" plan, three channel plans, and six tunnel-channel combination plans. Flood warning and zoning (flood plain regulation) are considered to be features of all alternatives.

The Recommended Plan for flood damage reduction basically consists of an improved 35- to 50-foot bottom width, grass-lined channel for 8,800 feet in the upstream portion of Shoal Creek; a 3,200 feet of 40- to 50-foot bottom width, concrete-lined channel in Hancock Creek (Shoal Creek tributary); and two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends approximately 400 feet downstream of Foster Lane. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall on Lake Austin near Bull Creek. The lower tunnel system consists of an intake on Shoal Creek in Pease Park near 19th Street, and an outfall with stilling basin in a small drainage tributary just south of the Missouri Pacific Railroad tracks near Pressler Avenue, and a 60-foot bottom width, grass-lined channel linking the stilling basin with Town Lake. All tunnel intakes are accompanied with diversion structures, and both outfalls are accompanied with stilling basins. The Northwest Park diversion will allow the passage of flows of 1,000 cubic feet per second of flow downstream, before water spills into the tunnel. The 19th Street Tunnel diversion structure will allow low flows to pass by a 42-inch culvert through the diversion dam. In addition, improvements on Hancock Creek include a concrete U-wall channel from Houston Street to Burnet Road; an attached box culvert under a shopping center; and a concrete channel continuing from the box culvert above Hancock Drive, transitioning to a grass-lined channel, and ending about 700 feet downstream of Hancock Drive.

The Recommended Plan also includes a linear recreation plan. The recreation plan includes a 1.4-mile trail for hiking, biking, and nature study, and park benches. Recreation average annual benefits are $77,000, and annual charges are $30,000 which includes $10,000 for operation, maintenance, and replacement. The recreational benefit-to-cost ratio is 2.6 to 1.0. The annual charges and annual benefits of the recreation are included in the cost for the Recommended Plan.

This plan will require the disposal of approximately 727,000 cubic yards of excavated materials. The city has identified two sites located near southeast Austin as disposal sites. Investigation of these sites did not reveal any problems from and environmental and cultural resources standpoint. The excavated material which will consist mainly of rock 8 to 10 inches in diameter will not be placed in any waters of the United States.

An evaluation of the plan from an environmental standpoint has been made and it has been determined that no mitigation for the proposed project would be required.

The Recommended Plan has a first cost of $82,272,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of $39,000 annually; and average annual benefits of $11,974,000. The Recommended Plan is the NED plan.

An Environmental Assessment has been made of the Recommended Plan and its alternatives. The proposed action meets the criteria as specified by Section 404(b)(1) guidelines of the Clean Water Act. Based on the Environmental Assessment and results of coordination, I have concluded that the proposed action will not have a significant adverse effect on the human environment nor is it environmentally controversial. Therefore, the preparation of an Environmental Impact Statement is not required.

16 Aug 91
(date)

William D. Brown
Colonel, Corps of Engineers
District Engineer

APPENDIX A

ENVIRONMENTAL ASSESSMENT

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3	Pollutant Concentration in Lake Austin below Bull Creek under Different Diversion Scenarios (One of the Worst Cases, the Month of May)	EA-46

EXHIBITS

Number	Title	Page
1	USFWS Letter dated June 15, 1983	EA-57
2	USFWS Letter dated June 11, 1984	EA-63
3	USFWS Letter dated October 1, 1985	EA-68
4	Section 2(b) Coordination Act Report	EA-72
5	USFWS Letter dated September 25,1989	EA-82
6	Section 404(b)(1) Evaluation	EA-84
7	Texas Historical Commission Letter dated October 29, 1982	EA-93
8	Texas Historical Commission Letter dated January 14, 1986	EA-94
9	Texas Historical Commission Letter dated June 16, 1989	EA-95
10	Draft Public Notice	EA-96
11	Environmental Protection Agency Letter dated April 16, 1990	EA-99

ENVIRONMENTAL ASSESSMENT

SUMMARY

FACTORS CONSIDERED

This Environmental Assessment considers several basic structural and nonstructural protection measures to correct flooding problems along Shoal Creek in Austin, Texas. A "no action" alternative was also compared with the above flood protection measures. Shoal Creek is a tributary of the Colorado River. The Shoal Creek study area is located in the west central part of the city of Austin, Texas. Except for a small undeveloped portion of the upper watershed, Shoal Creek is surrounded by an established urban area. Factors considered in this evaluation include socioeconomic values, cultural resources, riparian vegetation and wildlife, water quality, aquatic systems, and parks and recreation.

PREVIOUS ENVIRONMENTAL EVALUATIONS

Several environmental evaluations have been conducted since the Corps study was first initiated in 1981. After the reconnaissance report was completed in December 1981, an initial array of alternatives was developed. Individual plan types considered included channels, tunnels, tunnel/channel combination plans, and a no-action plan. In 1986, the Corps produced a plan formulation data report. In the environmental assessment of this report, the Corps identified that plans consisting of channelizing the major portion of the stream would incur the greatest environmental impacts among plan types. This report recommended a plan consisting of partial channelization and two separate tunnel systems diverting high flows to Lake Austin. Both systems used a tunnel diameter of 18.5 feet. In the draft interim report of June 1987, environmental effects were addressed in further detail. At a subsequent public meeting on August 12, 1987, the Corps heard public concerns over the location of tunnel outlets and potential water quality impacts to Lake Austin. As a result of these concerns, the Corps with the assistance of the City of Austin further studied the water quality impacts of Shoal Creek diversions on Lake Austin. Based on further review, Corps revised the plan recommended earlier to lessen potential impacts. The revised plan includes a smaller tunnel diameter, a inlet structure and diversion dam revision to allow fewer diversions, and relocation of one tunnel outlet from Lake Austin to Town Lake. The potential impacts of this revised plan are addressed in this environmental assessment.

MAJOR CONCLUSIONS AND FINDINGS

Initially, several basic structural and nonstructural measures were studied. Structural measures included detention reservoirs, channel improvements, levees, and tunnels. Basic nonstructural measures included flood proofing, zoning, permanent evacuation, and flood warning. After the initial analysis, ten alternatives were investigated in detail. The ten alternatives included a "no action" plan, three channel plans, and six tunnel-channel combination plans. The "no action" alternative simply

pertains to the probable future condition of the study area in the absence of a structural or nonstructural plan to reduce damages. After a detailed analysis, the optimum plan was selected from the above array of alternatives. The Recommended Plan is known as the 14-foot tunnel/channel plan. The Recommended Plan is basically composed of two types of improvements: channelization and diversion through tunnels. This plan consists of the following features.

o An improved 50-foot bottom width channel above US Highway 183 extending to the downstream side of the MOPAC railroad.

o Two 11-foot conduits under US Highway 183.

o A channel improvement with 35- to 50-foot bottom widths extending from US Highway 183 to just below Foster Lane. This improvement consists of a trapezoidal grass-lined channel.

o A 14-foot diameter tunnel diversion (Northwest Park Tunnel) just above Northwest Park that empties into Lake Austin just downstream of Bull Creek. Diversions to Lake Austin would occur approximately 1-2 times a year.

o A 14-foot diameter tunnel diversion (19th Street Tunnel) in Pease Park just west of where 19th Street intersects Lamar Boulevard. The tunnel outlet connecting stilling basin lies immediately south of Missouri Pacific Railroad tracks (southeast of the end of Pressler Street).

o A 60-foot bottom width grass-lined trapezoidal channel connects to the 19th Street Tunnel outlet, passes (approximately 820 feet) through a park area, and empties into Town Lake.

o On Hancock Creek (Shoal Creek tributary), concrete U-wall channel from Houston Street to Burnet Road. A box culvert would divert water under the shopping center and rejoin the creek just above Hancock Drive. Below Hancock Drive, the channel would transition to a grass-lined channel and end about 700 feet downstream of Hancock Drive.

o Intake and diversion structures are designed similarly for both tunnel diversion points. Diversion water flows over a weir into the tunnel inlet. At Northwest Park, the channel will be partially blocked by a channel weir wall which will allow the passage of flows up to 1,000 cubic feet per second (cfs) downstream. At Pease Park, the small diversion dam will be perforated with a 42-inch diameter conduit to pass flows downstream.

o Stilling basins will also be located at the two tunnel outlet areas to reduce diversion water velocity.

o A linear recreational plan is also included as part of the recommended plan. The recreation plan consists of a 1.4-mile hike/bike trail with park benches for rest stops. Recreation average annual benefits are $77,000 and annual charges are $30,000 which includes $10,000 for operation, maintenance, and replacements. The recreational

benefit cost ratio is 2.6 to 1.0. The annual charges and benefits of the recreation plan are included in the recommended plan.

The Recommended Plan has a first cost of $81,886,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of $39,000 annually; and average annual benefits of $11,945,000. It is considered to be the NED plan.

In brief, the Recommended Plan will not significantly impact the environment. If constructed, the environment will be affected in the following ways.

o **Cultural Resources**. No significant cultural resource sites are known to exist within planned construction areas of Shoal Creek. However, both tunnel outlets require additional study to complete the search for cultural resources, and outlets should be carefully placed to avoid any significant sites. Also, a small portion of historic Pease Park will require close examination under the present recommendation for a tunnel inlet here. During construction, if any archeological materials are discovered, construction activities will cease and the project archeologist will be notified. Subsequent protective measures and consultation will be conducted as required by Section 106 of the National Historic Preservation Act, as amended.

o **Recreation**. By constructing the recommended plan instead of a large comprehensive channel along Shoal Creek, significant removal of park areas and aesthetic hike/bike trails are avoided. Tunnel intake structures in Northwest Park and Pease Park will be designed to be aesthetically acceptable with low profiles, berming, structural coloring, and adjacent tree and shrub plantings as needed. In Pease Park, one or two frisbee goals may need to be moved, but there is still sufficient land for the frisbee course. As a result of the outlet channel passing through Deep Eddy Park near Town Lake, two baseball fields, some concession buildings, and a service road will be moved slightly west of their present location. A foot bridge for pedestrian trail is included near Town Lake. Since Deep Eddy Park was acquired with Park Service funds, additional park land would be needed to replace 3-acre recreational area loss from the construction of the project stilling basin and connecting channel. Another alternative under consideration is the construction of a scenic recreational lagoon instead of purchasing additional land for recreation. The proposed project will not significantly effect water quality for recreational purposes. The city has also shown an interest in the construction of an optional hike/bike trail extension along the upper Shoal Creek channel construction.

o **Terrestrial Wildlife**. No significant losses of flora and fauna are expected to occur near construction areas. Channelization of the Recommended Plan will occur in the upper watershed of Shoal Creek where trees near the stream are sparse, on two short reaches of Hancock Creek where relatively few large and small trees lie scattered along the tributary, and below the stilling basin of the 19th Street Tunnel outlet in an area which is a grass field. Few trees will be removed near Shoal Creek diversion points and outlet areas, and sufficient and similar

habitat lies adjacent to these affected areas to accommodate displaced wildlife in these areas. Furthermore, according to the city tree replacement program, trees lost to project construction will be replaced with equivalent wooded stands along treeless areas of Shoal Creek.

o Water Quality and Aquatic Life. No significant water quality and aquatic life impacts are expected to occur to Shoal Creek or downstream Town Lake. Sufficient flows will be passed downstream Shoal Creek to sustain aquatic life. What Town Lake loses in diversion waters should be made up from increased releases from Lake Austin. Lake Austin water quality will change only slightly with Shoal Creek diversions (approximately 1-2 diversions per year). Relatively small loads of phosphorus and other nutrients from Shoal Creek will be added to existing lake nutrients and should cause only a very slight increase in algal blooms. These algal blooms would not significantly impact the existing aquatic life within Lake Austin. Pesticides, herbicides, and other toxics would not be present in sufficient quantities in diverted waters to affect the safety of the public water supply or aquatic life of either lake. Turbidity will temporarily increase on Shoal Creek and near outlets near lakes during construction. Proper spoil containment will prevent any serious effects to lakes.

o Public Welfare. Public water supplies at Lake Austin and Town Lake will not be changed significantly in quality to affect water treatment or public health. During construction activities, noise levels will temporarily increase, particularly near tunnel openings and channel excavation. Activities should be restricted to normal workday hours to minimize public annoyances. To provide access to the Lake Austin outlet for tunnel construction, narrow roads will be widened and improved to accommodate trucks carrying tunnel spoil and equipment. Since Lake Austin is a near-constant level lake, it is also important to shoreline residents that water diversions from Shoal Creek do not cause property damage or loss of life. With the project tunnels in place, it will be necessary to consider storm conditions over the Shoal Creek watershed as other upstream areas contributing inflows to Lake Austin. Releases should be made from area lakes as they are similarly operated now to prevent flood damages. However, Shoal Creek flood plain residents who have had no immediate means of flood protection will substantially benefit in a significant reduction of flood losses.

Two important recommendations should accommodate the implementation of the Recommended Plan.

a. Shoal Creek watershed areas above Northwest Park diversion should be managed to assure that stormwater does not significantly impact Lake Austin water quality. Watershed development above US Highway 183 should be restricted similarly to development along Lake Austin. Illegal pollutant discharges and litter should be prevented to restrict nutrients and any toxics from entering Lake Austin.

b. Shoal Creek stormwater flows should be accounted for in the operation releases of Lake Travis and Lake Austin to prevent flooding of Lake Austin shoreline residences.

AREAS OF CONTROVERSY

At the public meeting held on August 12, 1987, many individuals expressed their concern over the locations first chosen for the two tunnel outlets. The first recommended plan included tunnels of 18.5-foot diameter and two outlets on Lake Austin. In the first plan, the Northwest Tunnel outlet was located on Dry Creek cove near several residences, and the 45th Street Tunnel outlet was located near Laguna Gloria Art Center and Mayfield Park. As a result of public concerns, the tunnel plans in the first recommended plan were changed to have less impacts on the Lake Austin community and water quality. The present revised recommended plan includes two smaller tunnels with one discharging into Town Lake and the other discharging just downstream of Bull Creek on Lake Austin. In addition, the revised plan calls for a much smaller diversion to Lake Austin that only occurs when Shoal Creek flows exceed 1000 cfs. The resulting diversions would include only the overflows in excess of instream flow of 1000 cfs. As result, spills to Lake Austin would occur only 1 or 2 times a year as opposed to 9 or 10 times with the previous plan. Therefore, no controversial issues are expected with the revised recommended plan.

UNRESOLVED ISSUES

There are no known unresolved issues at this time. Two disposal sites have been identified by the city of Austin. Investigation of these sites does not reveal any problems from an environmental and cultural resources standpoint. If these sites are not available at the time of project construction, new sites will be evaluated. In any event, excavated material would not be deposited in any waters of the United States.

RELATIONSHIP TO ENVIRONMENTAL REQUIREMENTS

This evaluation was conducted in compliance with and regard to the requirements of the following laws, regulations, and Executive Orders pertaining to Federally permitted water resource projects.

1. Clean Air Act, as amended.
2. Clean Water Act, as amended.
3. Endangered Species Act of 1973, as amended.
4. Executive Order 11988, May 24, 1977, Flood Plain Management.
5. Executive Order 11990, May 24, 1977, Protection of Wetlands.
6. Fish and Wildlife Coordination Act, as amended.
7. National Environmental Policy Act of 1969, as amended.
8. National Historic Preservation Act of 1966, as amended.
9. Watershed Protection and Flood Prevention Act, as amended.

Coordination has been maintained with USFWS throughout the course of the study as specified by the Fish and Wildlife Coordination Act (see environmental exhibits 1 through 5). The Section 2(b) report has been

incorporated into this assessment (see environmental exhibit 4). USFWS has been notified of plan revisions throughout the course of study. Environment exhibit 5 is a response to the most recent plan revisions.

Since the Recommended Plan affects watersheds of both Shoal Creek and Lake Austin, it is necessary to consider the environmental impacts in both areas.

The proposed action will not affect any species listed or proposed for listing as threatened or endangered or their habitats, under the Endangered Species Act. In a letter dated September 25, 1989 (environmental exhibit 5), USFWS has identified six species listed as endangered in Travis County. They are the black-capped vireo, Bee Creek cave harvestman, Kretschmar cave mold beetle, Tooth Cave psuedoscorpion, Tooth Cave ground beetle, and Tooth Cave spider. However, they stated that they do not anticipate that the amended project will have an impact on endangered or threatened species.

As required by the Clean Water Act, a Section 404(b)(1) evaluation has been completed and will be transmitted with this assessment (exhibit 6 of Environmental Exhibits) to the Texas Water Commission for State water quality certification for discharge of fill material (as required by Section 401 of the Clean Water Act) into waters of the United States. After review, a statement of compliance or noncompliance will be included in the Environmental Assessment. Disposal of excess material during construction of the project will occur in areas above the normal high water mark of any waters of the United States.

In compliance with the spirit and intent of Executive Orders 11988 and 11990, the Recommended Plan avoids work in, or adverse impact on, flood plains and wetlands to the extent practicable.

Apart from the tunnel outlet locations, the identification (survey) phase of Section 106 procedures of the National Historic Preservation Act is largely complete, with few cultural resources known to be present. Identification studies remain incomplete for the tunnel outlet areas (the Bull Creek area, in particular) and other impact areas such as haul roads or deposition areas. Evaluation is needed for the portion of Pease Park that may be affected under the current recommendation for a tunnel inlet to be placed here. Any emergency discoveries of cultural resources during construction will be treated under provisions of the National Historic Preservation Act.

STUDY AUTHORITY

The city of Austin has suffered from frequent flooding caused by Shoal Creek. Flash flooding has occurred through the years with the more damaging storms recorded in April 1915, November 1974, April 1975, and the most recent, May 1981. During May 24-25, 1981, 13 deaths occurred due to drowning, with 5 of these deaths on Shoal Creek. In July 1981, at the request of Mayor Carole Keeton McClellan, a study was undertaken by the Corps of Engineers to determine the need for Federal participation in a project to alleviate these conditions under the continuing authority

provided to the Chief of Engineers by Section 205 of the Flood Control Act of 1948, as amended. The Reconnaissance Report prepared in December 1981 under that authority recommended that additional study of the flood problem be accomplished under the Corps' General Investigation Program, specifically under the Colorado River and Tributaries authorization. This study is being accomplished as a partial response to Congressional direction in the Flood Control Act approved June 22, 1936; Resolution by the Committee on Commerce, United States, adopted August 4, 1936; River and Harbor Act approved August 26, 1937; and River and Harbor Act approved March 2, 1945.

PUBLIC CONCERNS

The study was conducted with the cooperation and assistance of the city of Austin, area residents, and commercial interests. Coordination was maintained throughout the study with local officials. As noted earlier, several individuals at the public meeting held August 12, 1987, expressed their concern over two outfalls affecting Lake Austin water quality, lakeside aesthetics, and nearby lake residences. Because of these public concerns, the Corps revised the recommended plan by changing both tunnel outlet locations (moving one outlet to Town Lake) and by reducing the flows diverted to lakes. Flow diversion structures to Lake Austin were scaled down based on recommendations of the city who conducted a water quality diversion analysis. These revisions substantially reduce potential impacts over the previous recommended plan. The revised recommended plan will not incur any significant environmental impacts and should after further public involvement be generally acceptable to the public.

PLANNING OBJECTIVES

The primary Federal objective in water resource planning is National Economic Development (NED). Additional planning objectives have evolved through interviews with area residents; contact with city, State, and Federal agencies; and from observations made in the study area. These additional planning objectives include:

- Reduce flood damages within the city of Austin.
- Provide flood control to improve health and safety within the city of Austin.
- Prevent the frequent flooding in Austin which causes loss of jobs and/or homes.
- Maintain and/or enhance the fish and wildlife resources within the city of Austin.

AFFECTED ENVIRONMENT

DESCRIPTION OF STUDY AREA

The Shoal Creek study area is located in the west central part of the city of Austin, Texas (see figure 1). Shoal Creek, a tributary of the Colorado River, originates in the northwestern portion of the city and flows southeasterly. Town Lake on the Colorado River directly receives Shoal Creek flows. With respect to major city roads, the stream lies east of and almost parallel to State Highway Loop 1 and intersects US Highway 183 in the upstream area and First Street in the downstream area.

Within a city of rapid growth and development, Shoal Creek provides a natural and recreational setting to an urbanized area. Significant portions bordering the stream are greenbelt and park land areas with established hike and bike trails. Other areas adjacent and outlying are residential, commercial, and industrial.

Shoal Creek lies within the Blackland Prairie vegetational region, very close to the east edge of the Edwards Plateau. The soils along the creek include various types of clays with underlying or outcropping limestone rock. Wooded areas consist of live oaks, sugarberry, pecans, elms, willows, mulberries, and other diverse tree types. In some areas, the original tree canopy and understory remain relatively intact with ample wildlife habitat. In overbank park areas where the original understory has been removed, mown grasses now reside.

Drainage area of the Shoal Creek watershed is approximately 13.2 square miles. The creek is intermittent with numerous permanent stretches of water. The upper reaches of the creek are mostly dry except after rains.

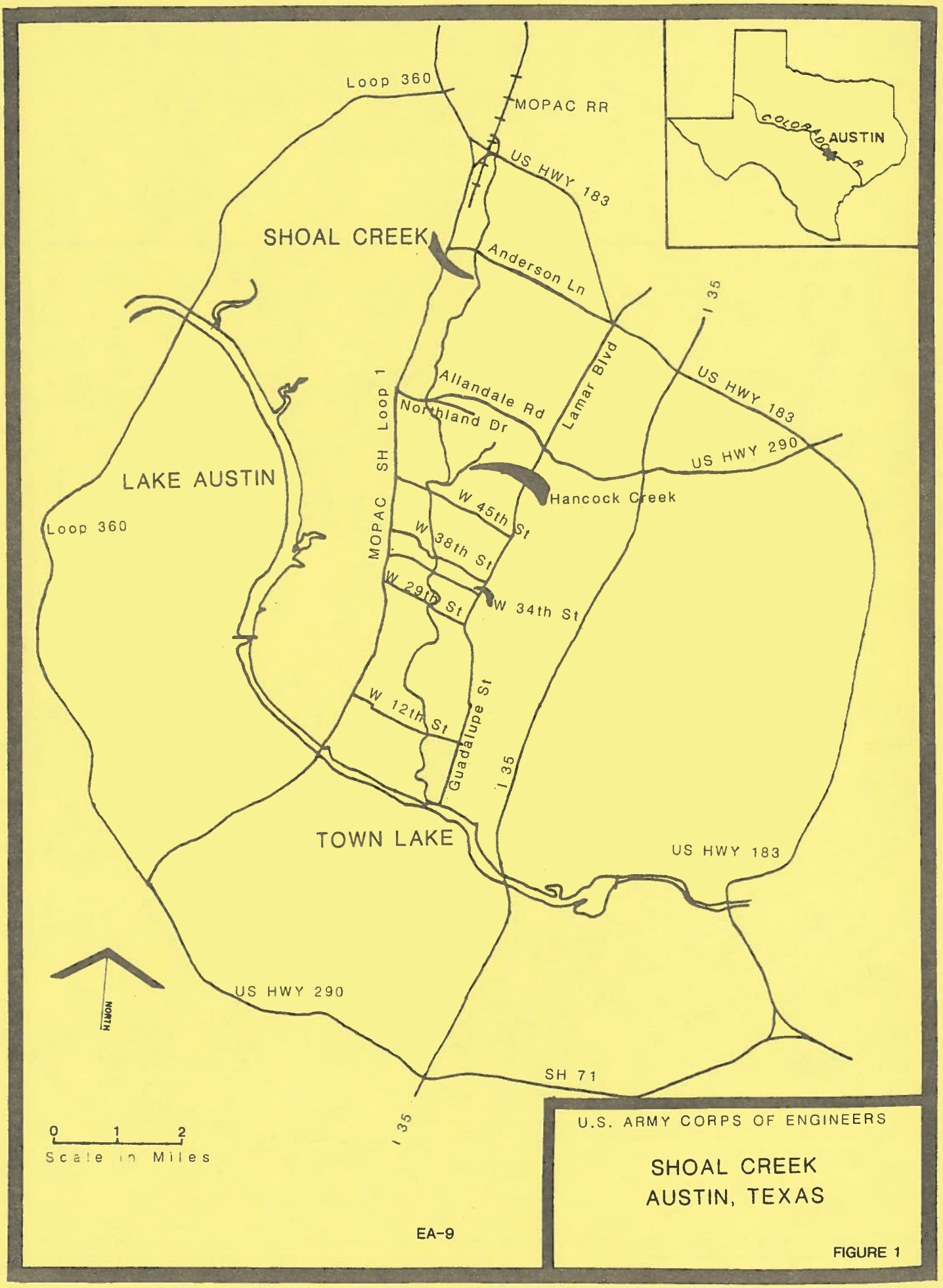
GEOLOGICAL ELEMENTS

Geological Setting

Most of Shoal Creek watershed is located within the Balcones fault zone. Approximately 30 percent of the watershed lies outside of the zone and immediately west of the Mount Bonnell Fault in the upstream area. The stream intersects several dip slip normal faults. Within the upstream and middle reaches, erosion has exposed several geologic formations: Edwards Formation, Del Rio Formation, Buda Formation, Eagle Ford Formation, and the Austin Group Formations. In downstream areas, streambed and channel banks are composed of Recent alluvium, tributary terrace deposits, and lower Colorado River terrace deposits.

Mineral Resources

Sand, gravel, limestone, oil, and gas are important mineral resources within the Austin area. Within the immediate project vicinity, which is predominately residential, there is no significant production of these resources.



U.S. ARMY CORPS OF ENGINEERS

SHOAL CREEK
AUSTIN, TEXAS

FIGURE 1

Topography

Topography of the Shoal Creek watershed area is moderately dissected, and slopes are commonly less than 5 percent except in a few local areas. The stream slope averages 30.5 feet per mile (0.58 percent slope).

Soils

Shoal Creek watershed is composed of several types of bedrock and alluvial soils. Bedrock soils are more predominate in middle and upper reaches of the stream and consist of dark brown to gray brown calcareous silty and clay loams of 7- to 6-inch depth; dark brown to reddish-brown calcareous clays, clay loams, and stony clays of less than 20-inch depth; and dark gray, brown, and olive calcareous clays and clay loams of 12- to 36-inch depth. Alluvial soils predominate in the downstream reaches and consist of dark gray calcareous clay and clay loam of about 38-inch depth; brown to red-brown calcareous sandy loams, silty clay loams, and gravely sands of 12- to 20-inch depth; and light brown to brown calcareous silt loams, silty clay loams, and sandy loams of 12- to 20-inch depth.

HYDROLOGIC ELEMENTS

Climatology

The Austin climate is generally mild with hot summers. The National Weather Service has a first order recording station at Austin, Texas. Temperatures vary in monthly averages from a low of 41 degrees in January, to a high of 95 degrees F in July. Maximum and minimum recorded temperatures are 109 degrees F in July 1954 and -2 degrees F in January 1949, respectively. The precipitation record at Austin is almost continuous since 1856. The maximum monthly and maximum 24-hour rainfall in the Austin area were 20.78 inches in September 1921, and 19.03 inches on 9 September 1921, respectively. The annual mean rainfall is approximately 33 inches. The annual maximum and minimum rainfalls are 64.68 inches and 11.42 inches, respectively. Mean annual snowfall is 1.2 inches. Wind speed averages 9.3 mph annually.

Surface Waters and Water Quality

The major watercourse in the Austin area is the Colorado River, which is fed by its numerous tributaries which include Barton, Bull, Shoal, Boggy, Bear, Walnut, Waller, and Williamson. The Colorado River bisects the city of Austin and is impounded in two riverine reservoirs, Lake Austin and Town Lake within the city of Austin. Both reservoirs also receive flows from adjacent springs.

Lake Austin is a popular recreational area, as well as the principal source of drinking water for the city's populace. The major tributary of Lake Austin is Bull Creek. This watershed is currently mostly undeveloped but is developing very rapidly. The city of Austin treats raw water from Lake Austin at its Ullrich and Davis water treatment plants (WTP). Ullrich WTP and Davis WTP have respective design treatment capacities of 60 and 120 million gallons per day (mgd). The intake for Ullrich WTP is

located near the west bank near the mouth of Bee Creek. The intake for Davis WTP is located near the east bank at Huck's Slough.

The Town Lake watershed consists of much of the urban core area, and the lake serves as an auxiliary drinking water source and recreational area. The lake receives substantial quantities of urban stormwater runoff from primarily high-density residential and commercial areas. Shoal, Waller, and Barton Creeks are the main tributaries of Town Lake. Several major creeks enter the Colorado River below Town Lake dam, including Boggy, Walnut, and Onion Creeks. Barton Creek, along with parts of Onion Creek and its tributaries Williamson, Bear, and Slaughter Creeks, are in the Edwards aquifer recharge zone. Green WTP has a design treatment capacity of 45 mgd and currently draws water from Town Lake upstream of the Shoal Creek mouth.

In recent years, the city of Austin has taken steps to address runoff pollution of Lake Austin and the Edwards Aquifer. A series of ordinances were passed in 1980 and 1981 to regulate new developments in the various watersheds in the Austin area. Among other provisions, they restrict housing density, limit the amount of "impervious cover" (roofs or paved areas that do not absorb water and hasten runoff), and require erosion controls and storm water detention.

Lake Austin water quality is generally better than Town Lake. Both are generally compliant with their respective state surface water quality standards (Stream Segments 1403 and 1402). Both lake water qualities are very similar with regards to dissolved oxygen, pH, chlorides, sulfates, total dissolved solids, and temperature. However, Town Lake has had much higher concentrations of fecal coliforms.

In a direct comparison of Shoal Creek water quality with Lake Austin and Town Lake water qualities, total dissolved solids, total hardness, chlorides, and sulfates concentrations in Shoal Creek are similar to both lakes. However, nutrients in the form of BOD, phosphorus, and ammonia are much higher in concentrations than those found in either lake. According to past data, fecal coliform concentrations are also much higher than those found in either lake. Several metals and pesticides have also been found in higher concentrations than either lake.

Since there are no significant point source pollution discharges into either Lake Austin or Town Lake, stormwater runoff pollutant load is considered to be the principal contributing factor impacting the water quality of Austin area creeks and thus the lakes.

Although Barton Creek is the largest of all creeks that flow into Town Lake, Shoal Creek pollutant concentrations are generally higher than that of Barton Creek. As an example, in a 1984 stormwater quality study of Austin creeks, the city of Austin reported that Shoal Creek at 12th Street had an exceptionally high fecal coliform concentrations with a log mean of 2281 fecal coliforms/100 ml, as compared to the 26 fecal coliforms/100 ml of Barton Creek.

The Shoal Creek watershed is entirely within the Austin city limits and has a drainage area of about 13 square miles, with 47 percent impervious cover. The watershed of the creek is almost fully developed, and thus the creek has heavy urban pollutant loadings. Road, street, and parking lot surfaces will collect automotive residues (gasoline, oil, exhaust particulates, etc.), street litter, dust, and other road debris. Commercial and residential lawns contribute grass and shrub clippings, pesticides, and fertilizers in runoff. Although a minor contaminant to runoff pollution, air pollutants from industrial exhausts and vehicle emissions should settle onto and be washed from impervious surfaces. Along the stream, hikers may occasionally discard garbage such as cups, cans, and bottles. Stream waters of Shoal Creek may also become contaminated from uncovered sewage manholes on the stream bed.

Due to the differences in land use within the Shoal Creek basin, pollutants will not be uniformly distributed along the watercourse. Water quality of Shoal Creek at Northwest Park is slightly better than that of Shoal Creek at 12th Street. Downstream areas adjacent to Shoal Creek are highly urbanized with commercial lots. In these areas, sidewalks, streets, and parking lots provide impervious surfaces for pollutants to settle before runoff carries them to the creek. In addition, older wastewater and storm sewers near downtown areas may leak allowing pollutants to reach Shoal Creek. As a result, higher concentrations of various oils, organics, phosphorus, BOD, fecal coliform bacteria, and other contaminants are expected to enter Shoal Creek in the downstream reaches than the upstream reaches. In the middle and upstream reaches, commercial land use is less and residential lots predominate. Natural and vegetated areas are broader in general and allow more opportunities for pollutants to be absorbed rather than be transported to the creek.

Shoal Creek water contains a higher concentration of toxic substances as compared to the runoff water of Lake Austin tributaries. These include substances toxic to humans and/or aquatic life such as arsenic, copper, lead, zinc, polychlorinated biphenols, chlordane, DDD, DDE, DDT, diazinon, pyrene, and PAHs. Shoal Creek waters enter Town Lake but do not significantly affect the use of the lake as a city raw water supply.

Ground Water

Within the Austin and adjacent outlying areas, the principal source of water for rural areas, communities, industries, and small towns is the aquifers within the basal Cretaceous Trinity Sands and the Edwards Formation. Minor aquifers are found in the low level alluvial deposits and dolomite limestone of the Glen Rose Formation.

Within the vicinity of Shoal Creek, the dolomite and dolomitic limestone strata of the Edwards Formation provide a source of ground water at shallower depths than the basal Cretaceous Trinity Sands. Depths to well water surface vary from about 15 to 315 feet within the Shoal Creek area. A few wells are located within and along the fringes of the watershed and are not major sources of water supply.

Many natural springs are present in the Austin area. In general, the natural springs are formed from outcrops of Edwards Formation or fractures intersecting waterbearing strata of the Edwards Formation. Some of the natural springs in the area include Taylor (or Mormon) Springs, Mount Bonnell Springs, Powerhouse Springs, Barton Springs, and Sieder Springs. Discharges from Taylor, Mount Bonnell, and Powerhouse Springs flow into Lake Austin, and discharges from Barton Springs and Sieder Springs flow into Town Lake. The upstream portion of Shoal Creek Watershed west of Mount Bonnell Fault acts as part of a larger Edwards recharge area for Taylor and Mount Bonnell Springs just north of Tom Miller dam (Lake Austin dam) and possibly Powerhouse Springs near the dam. Within the immediate study area, Sieder Springs are located between 34th and 38th Streets along Shoal Creek with flows ranging from 0.02 cfs to 0.32 cfs and are primarily a historical point of interest.

CULTURAL RESOURCES

Concerning formally recorded archeological sites, five previously recorded sites and one newly recorded site are presently known to exist in the broadest limits of the study area. In addition, three cultural resource locations without formal archeological site designations (lacking trinomial labels) are currently known in the study area: the historic Franz Fiset dam, the Sieder Oaks Texas Historic Landmark, and historic Pease Park. Other archeological sites and a National Register Property were identified during earlier phases of study in 1985. These findings are not identified here because they are not now in the present study area.

Six archeological sites are located along Shoal Creek. Three of these archeological sites are prehistoric and are now covered by residential development. The other three sites on Shoal Creek are historic. One is the Lamar Street Dump Site which outcrops along Shoal Creek north of 24th Street. A second historic site located south of 29th Street could be a homesite or a trash dump. The other site is a late 19th and early 20th century house and pen located on west side of MOPAC railroad north of US Highway 183. Additional isolated artifacts and two small historic scatters observed on Shoal Creek could not be associated with sites.

The marker for the "Recorded Texas Historic Landmark" for Sieders Oaks depicts the site of a historic settlement and Indian massacre located on the Hike and Bike Trail on the west side of Shoal Creek at 35th Street. Several varieties of native Texas oaks date to the historic settlement situated along an old wagon trail, which is now the Hike and Bike Trail. Across the stream bed from Sieder Oaks Texas Historic Landmark are two springs, Sieder Springs. In 1839, these springs were described as a possible water supply for the new capital. Fort Austin and other army camps used the springs between 1847 and 1865. The springs became a popular resort and a bath house was operated here by the Sieders family until 1896.

The Franz Fiset Dam was observed on Shoal Creek just below 49th Street. The dam appears to be cut rock (probably limestone) and dates to 1896.

Pease Park, dedicated in 1875 and possibly the first park of the City of Austin, is located along Shoal Creek between Windsor Road and West 15th (Enfield Road). The park may be viewed as historic because of its overall age and its association with various events and persons of historical interest.

Other details of these prehistoric and historic areas are described in detail in appendix B of the report.

PALEONTOLOGICAL RESOURCES

The possible occurrence of scientifically important paleontological resources (fossils associated with contexts before human occupation of the area, and generally older than 20,000 years in age) in the study area has been considered. At this time no significant paleontological resources are known in the proposed construction areas other than in the upper portion of Shoal Creek where channelization is planned. Plesiosaur (swimming dinosaur) remains were excavated here in early 1990 by staff of the Texas Memorial Museum. This paleontological find will be completely removed long before any channelization may occur, and it does not appear that any portions of the find are concealed by geologic strata (personal communication between Dr. Ernest Lundelius, U.T. Austin, and Erwin Roemer, Corps archeologist, April 2, 1990). In general, environmental laws and regulations at federal, state, and local levels do not explicitly address paleontological resources. However, such natural resources fit under considerations of the National Environmental Policy Act, and paleontological materials will be considered as the project proceeds if such resources become identified to be clearly of scientific importance.

BIOLOGICAL SETTING

Shoal Creek lies within the Blackland Prairie vegetational region, very close to the eastern edge of the Edwards Plateau. Historically, this region was one of rolling hills and creek valleys with native prairie grasses dominating all but the creek banks where Texas sugarberry (hackberry), pecan, oaks, elms, cottonwoods, and other trees and shrubs formed wooded corridors.

Little farming was done along Shoal Creek as compared with the extensive agricultural activities a few miles to the east. This was due to its nearness to the rocky terrain of the Edwards Plateau and its early use as a residential area near the business district of the city. Today, most the creek borders residential, commercial, or park land with the exception of the undeveloped second growth areas near Highway 183.

Shoal Creek is above the headwaters of the Colorado River and is not considered a wild and scenic river. No Federally listed threatened or endangered species of plants or animals appear to be resident in the immediate study area. The proposed project could be located within the migratory route of the whooping crane (Grus americana) which is an endangered species; however, an initial review indicates that any work within the area will have no effect on the whooping crane or its habitat. In December 1986, USFWS proposed that the black-capped vireo (Vireo

atricapillus), a bird whose largest breeding population exists near Austin, Texas, be added to the U.S. List of Endangered and Threatened Species. The vireo and five other species of Travis County are now listed as endangered. The five species are the Bee Creek cave harvestman (Texella reddelli), Kretschmar cave mold beetle (Texamaurops reddelli), Tooth Cave psuedoscorpion (Microcreagris texana), Tooth Cave ground beetle (Rhadine persephone), and Tooth Cave spider (Leptoneta myopica). The golden-cheeked warbler (Dendroica chrysoparia) is also known to be present in the Austin area, and has recently been placed on the Emergency List for Endangered and Threatened Species. USFWS has indicated that no problems to endangered species are anticipated as a result of this project.

It is important to note that the city of Austin has a tree replacement program for public works. Trees lost to public works construction are required to be replaced with equivalent wooded stands.

The following is a description of the conditions observed for various stretches of Shoal Creek (see figure 1). USFWS in a planning aid letter dated June 15, 1983, described an existing condition of the creek and identified problems and needs of the Austin area. See exhibit 1. This information is also incorporated into the following reach-by-reach description of the watershed area.

Town Lake Confluence to 12th Street

Shoal Creek from Town Lake on the Colorado River to 12th Street is almost completely surrounded by commercial and residential development. Wildlife habitat is almost nonexistent, and the fisheries habitat is of low quality. Buildings and factories have encroached almost to the creekbank edges. Outfall structures and railroad trestles and bridges are also present. The creek is also adversely impacted by the quantity and quality of urban stormwater runoff which it receives.

Streambanks are mostly alluvial soils with occasional rocky cliffs. Excessive erosion has occurred in places. Retaining walls of concrete, rock, or wood have been constructed in several places. The vegetation is a thin, discontinuous strip immediately adjacent to the creek. Scattered trees include sugarberry, mulberry, liveoak, and elm. Some chinaberry, ash, and pecan are intermixed. Grasses, along with other herbaceous species occur in the creekbed and along the banks. Trash litters the creekbed along much of this section.

Along the eastern side of Shoal Creek is an exception to the above description. The park consists of an open grassy area just south of 10th Street and extending approximately to the projected position of 9th Street and a thicket extending for about one more block to the south. The thicket contains a rather dense growth of medium to small trees, shrubs, and vines. The trees making up the canopy include mainly liveoak, Texas sugarberry, and elm. Also present are pecan, Arizona walnut, chinaberry, eastern red cedar, peach, black willow, white mulberry, box elder, and sycamore. The understory consists of small individuals of the tree species listed above, along with ligustrum and Japanese honeysuckle (which are dominant), dewberry, agarito, brier, poison ivy, mustang grape,

hawthorn, holly, privit, and others. The abundance of cultivated plants is probably due mainly to the use of the area by birds. The herbaceous flora is rich and diverse, especially in the seep area and along the creek bank.

12th Street to 29th Street

This area from 12th Street north to 29th Street consists of Shoal Creek Greenbelt and Pease Park. This intensively used urban greenbelt area contains approximately 80 acres of heavily wooded important wildlife habitat. This is also the site of the first public hike and bike trail in the United States.

Willow and mesquite are frequent, along with briar, grape, Japanese honeysuckle, correhuela, oleander, and large stands of giant reed. The creekbed is rocky along much of this stretch. One section at the bend where Gaston Avenue intersects Lamar Boulevard is concrete lined.

29th Street to 34th Street

Between 29th and 34th Streets, the creek cuts through a low narrow canyon with heavy vegetation along both banks. High cliffs rise on the west side with mosses and ferns growing along seeps. The creek is wide and rocky with little erosion apparent. Residential lots extend to the edges of the high cliffs on the west side and almost to the water's edge along portions of the gentler slopes on the east side past the bend.

The Scarbrough Bluff area is located at approximately the 3000 block on Shoal Creek. This heavily wooded, rugged terrain is virtually a hidden wilderness in the city. This area is very popular for trail users and university classes.

The Bryker Woods greenbelt area occurs at approximately the 3100 block north to 34th Street. Included in this tract are 7.5 acres of large live oaks and pecan trees.

34th Street to 38th Street

From 34th to 38th Streets, Shoal Creek is highly impacted by commercial development and roadway construction. Most of the understory has been removed, with only a few oaks and willows remaining. Creekbanks are bare or covered with grass. One high quality area in this reach is Seider Springs Park. This 5-acre urban park has an existing natural spring and is wooded with very large liveoaks. Flooding has required some gabion bank stabilization in this locale.

38th Street to 45th Street

Within this area from 38th Street to the approximate projected position of 42nd Street (near the Austin State School Annex property) is the Jefferson Street reach. This area suffered the most residential damage in the 1981 flood. Residences have been bought by the city, which has a scheduled channel project. Revegetation plans by the Parks and

Recreation Department will make it a significant natural greenbelt extension.

Midway to 45th Street, the creek is bordered by commercial and wooded residential lots on the west and mostly wooded open space on the east to Shoal Creek Boulevard. Tree cover consists of oaks and willows. Continuing to 45th Street, the west bank consists of undeveloped land, mostly cleared except for trees along the creekbank. The terrain around the Texas Records Building on the east bank is sparsely wooded. The creek is rocky, relatively undisturbed, and tree-lined through most of this stretch.

Occurring upstream is the Austin State School natural area consisting of approximately 20 acres of undeveloped creekside meadow and woodland. This area is cited by the Audubon Society as an important wildlife habitat in Austin. The area extends from approximately the 4200 block to 45th Street on both sides of the creek. A greenbelt trail extension has been proposed for this tract.

45th Street to Northland Drive and Hancock Creek

Between 45th and 49th Streets, the creek is rocky and intermittent with a broad flood plain immediately north of 45th Street, narrowing around the first bend as limestone cliffs rise on the south side and residential lots encroach on the north. On the west side of the second bend, residential lots continue to lie in the low adjacent flood plain. Limestone cliffs (20 feet high or more) continue around the second bend on the east side. Upstream of the bend, Hancock Creek cuts through the east bank cliffs and intersects Shoal Creek. Near 49th Street, the mainstream is bordered with cliffs on both sides. Heavily wooded areas bordering low banks and high cliffs create valuable urban wildlife habitat within this segment. At the projected position of 49th Street, the Franz Fiset Dam is a 15-foot high rock dam which dates to 1896 and spans between the limestone cliffs on the Shoal Creek mainstream.

Hancock Creek near its mouth to Shoal Creek Boulevard cuts through high limestone cliffs. Residential lots border cliff edges on both sides, and large trees beyond these edges shade much of the rock streambed below. Small isolated patches of mosses and ferns lie in several places on the vertical rock walls. Beyond Shoal Creek Boulevard, the tributary of Shoal Creek quickly narrows and tall grasses inhabit the streambed as soil cover thickens and rock cliffs disappear. The channel is well defined and is highly developed with commercial and residential structures very close to the channel banks. Along one section, the creek is diverted under a shopping center through box culverts.

On the mainstream, the small reservoir behind the dam narrows upstream near Hancock Drive where impoundment backwaters end and stream flows predominate. The reservoir behind the dam at 49th Street is fished by local residents. Due to its size and depth, it probably contains relatively large fish, possibly bass, catfish, and large sunfish. This portion of the creek should contain a greater number of invertebrate species due to its permanent nature and variety of habitats. The dam has

therefore been a beneficial addition to the creek, not only in providing recreation to local residents but also in increasing the aquatic species diversity. (Species diversity is often considered by ecologists as a measure of the "health" of a community. Given two similar habitats, the one supporting the higher species diversity is usually considered the "healthier" system.) The small pool just below the dam supports a number of redear turtles and bullfrogs.

Above Hancock Drive is a broad flood plain which progressively narrows toward Northland Drive. Limestone cliffs rise on the east in a narrow corridor with more gradually sloping terrain on the west. Austin Memorial Park Cemetery forms a natural forested area on the west side for half the distance between Hancock and Northland. The east side along this stretch is undeveloped west of Shoal Creek Boulevard. During the spring when the creek is under low, but steady flow conditions, a series of shallow water pools and small ripples dominate at several locations. In shallow water pools between the projected position of Shoalmont Drive (near Shoal Creek Boulevard) to Northland Drive, there reside many active spawning beds.

In the natural areas below Northland, the dominant overstory species are oak, elm, pecan, sugarberry, box elder, willow, bois d' arc, and cedar (in drier rocky areas especially). Understory and herbaceous cover include young of the above trees, Mexican buckeye, sumpweed, ligustrum, berberis, poison ivy, honeysuckle, grape, wild onion, turk's cap, spiderwort, and just below the dam on the east cliffs maidenhair fern, mosses, and liverworts. The best stands of natural vegetation occur in the stretch north of 45th Street and that bordered by the Austin Memorial Park below Northland. A small plum grove occurs along the latter stretch.

A 4-acre tract adjoining the Austin Memorial Park Cemetery and Northwest Recreation Center site provides a valuable urban green space in a highly developed residential area. This site is heavily wooded with liveoak and elm and is used by hikers and nature walkers. The area has been proposed as part of the Shoal Creek greenbelt trail extension. This Shoal Creek greenbelt area at Northland Drive serves as important urban wildlife habitat for fish, birds, and small mammals.

<u>Northland Drive to Anderson Lane</u>

From Northland Drive to Anderson Lane, the creek is narrow with residential lots encroaching. The terrain is rather flat, and erosion of the creekbanks is evident along much of this stretch. Concrete and/or rocks have been used in some areas to retard erosion. Creekbanks are mostly mowed grasses with large trees providing almost complete shade. Willow is invading in some sections.

Just south of Greenlawn Parkway is Northwest District Park, a heavily used 31-acre park with Shoal Creek on its western boundary. In addition to primary recreation facilities, this park once had a wooded natural area and a duck pond. However, the park has undergone extensive construction activity. The city of Austin is reconstructing the park to provide additional flood protection within the area. East of the creek, most of the park land is being excavated to form a high flow detention area and to

provide an open space recreational area. After the construction is completed, wooded areas will be confined to a narrow band of trees on the west bank of the creek and a few small wooded areas east of the park detention area adjacent to residential backyards.

At the lower end of Northwest Park, a thin strip of thick vegetation lines the western creekbanks. American elm, sugarberry, liveoak, and eastern red cedar are the dominant species.

Anderson Lane to Highway 183

The creek has been significantly altered. No representative stands of native vegetation exist in this stretch. Streambank vegetation is mostly mowed grasses with some invading willow and cattail. The land bordering the creek is residential, commercial, or is being filled and developed for commercial purposes. The stream more resembles a urban ditch in this area than an attractive watercourse.

North of Highway 183

North of Highway 183, the creek is small, shallow, and wet only after rains. In an area immediately north of the highway, the creek is basically a ditch that has been recently realigned to follow around the perimeter of a newly-constructed golf driving range. This immediate area has been heavily disturbed and has little habitat value. Beyond the driving range, the creek passes through cedar and sugarberry wooded area as it reaches its source in the rolling hills. Above the driving range, a typical hill country fauna is evident. Deer signs are not uncommon. Small mammals and a variety of songbirds are frequently encountered. The area is also interesting geologically where the head of the creek cuts into the western edge of the Balcones Escarpment. However, this area, too, is gradually changing as the area becomes urbanized.

Common Biota and Ecological Value

Shoal Creek area is an important ecological resource within a large urban setting of Austin. Several reach areas are of particular value due to stands of natural or semi-natural vegetation, wildlife habitat, and scenic limestone cliffs. These qualities also make these sections aesthetically valuable. The areas are the designated park land south of 10th Street and east of the creek; the park land between 29th and 34th Streets; 45th Street to Hancock Drive including the small reservoir; the upper half, bordered on the west by the Austin Memorial Park, of the stretch between Hancock Drive and Northland Drive; and the headwaters of the creek far north of Highway 183.

Raccoons, opossums, and fox squirrels frequent the wooded sections of the creek. A multitude of birds, both residents and migrants, take advantage of the food, nesting sites, vegetational cover, and water provided by the wooded streamside. The undeveloped area above Highway 183 once represented good wildlife habitat for typical hill country fauna, including deer, is now rapidly being changed with development.

Shoal Creek water quality is impacted by urban runoff and leakage from sewerlines. This is evident in some of the downstream pools by the dense algal growth, a low diversity of animal species dominated by pollution tolerant forms, and the presence of gas bubbles from nutrient rich bottoms of deeper pools. In one survey conducted in the early spring for the city, predominating organisms associated were one species of cladophora over other types of algae, chironomid among insects, rotifers among the microinvertebrates. The typical species of snails were pulmonate snails which are regarded as more pollution tolerant than gill-bearing forms.

Although the water quality is periodically affected by urban pollutants, the water quality of Shoal Creek is sufficient to support aquatic life. The most common fish in most areas are mosquito fish and a few species of minnows. Sunfish are present in the deeper, more permanent sections. Bass and catfish probably also occur in the large pools such as the reservoir below Hancock Drive. Common aquatic or semi-aquatic reptiles are redear turtles (which occur in large numbers at the 10th Street "turtle pond" and in and below the reservoir below Hancock Drive), common snapping turtles, mud turtles, western ribbon snakes, and water snakes. Bullfrogs, leopard frogs, and Gulf Coast toads frequent the creek as residents and/or spawners.

EXISTING RECREATION

The recreation market area for Shoal Creek basically is comprised of that portion of the city of Austin between Interstate Highway 35 on the east and Loop 1 (MOPAC) on the west and between the Colorado River on the south and U.S. Highway 183 on the north. It includes portions of both the central business district and the University of Texas campus. According to the 1980 census, there were approximately 62,000 persons living in this area, as compared with 345,900 for the city as a whole (17.9 percent). Although not part of the most rapidly growing sectors of Austin which are found on its periphery, particularly in the northwest and on the southwest, the central sector has experienced substantial increases in population in recent years. Most of this growth has resulted from the construction of multifamily housing units. Indeed, the city's 1984 Growth Watch Report indicates that housing in the area is overwhelmingly of the multifamily type. Consequently, population densities are among the highest to be found in Travis County.

This high population density, coupled with the demographic characteristics representative of a large student population, create a particularly great demand for recreation facilities. According to the 1985 Texas Outdoor Recreation Plan (TORP), this area can be expected to exhibit higher than average participation rates for boating, fishing, water skiing, swimming, and picnicking. In terms of actual participation rather than rate of participation, the most popular activities are walking, hiking, bicycling, jogging, and swimming. Based on population estimates and the TORP projections for recreation facility deficits, the following shortfall is identified for the Shoal Creek market area.

Facility/Resource	1985	1990	1995
Baseball field	2	3	4
Basketball court	4	5	6
Bicycling trail (mile)	8	9.7	11.3
Child's playground (acres)	2.8	3.9	4.9
Football fields	1	1	1
Golf holes	9	9	9
Jogging trail (mile)	2.0	2.5	3
Picnic tables	36	59	90
Soccer fields	2	3	3
Softball fields	4	6	8
Tennis courts	5	8	11
Walking trail (mile)	2.8	3.4	4.1

There are a number of existing recreation resources in the Shoal Creek study area. These include Northwest District Park (31 acres adjacent to the creek between FM 2222 and Anderson Lane), Seider Springs Park (5 acres between 34th and 38th Streets), Bryker Woods greenbelt area (7.5 acres south of 34th Street with trail linkage to Seider Springs Park), and Pease Park (approximately 80 acres between 29th and 15th Streets). Included in and partially connecting these parks is the Shoal Creek greenbelt with an extensively used hike and bike trail. Also within the Shoal Creek market area are Hancock Golf Course and portions of the Colorado River/Town Lake greenbelt system.

ENVIRONMENTAL ASSESSMENT OF PROJECT ALTERNATIVES

GENERAL

To reduce potential loss of life and flood damages, an array of project alternatives was initially investigated. Therefore, the discussion below outlines the general environmental impact of each basic type of improvement and follows with a brief description of specific plans initially considered. The recommended plan is discussed in further detail in the subsequent section.

BASIC ALTERNATIVES

No Action or Nonstructural Plans

A no action or nonstructural plan would have the least impact on the natural environment of Shoal Creek. A no action plan allows the existing stream to remain as it is with no flood protection requirement. Although this alternative has essentially no impacts on the natural setting, the plan requires the public to accept the continued risks to life and property.

Nonstructural plans include such plans as flood warning systems, flood proofing, flood plain zoning, and the relocation of residences and businesses. Unlike the no action plan, this plan incorporates flood

protection measures. However, these measures are rarely satisfactory alone and are usually combined with another plan. Flood warning systems, flood proofing, and flood plain zoning have no direct impacts on the natural environment. Relocation efforts may have only temporal effect during structural removal. Trash and housing debris may collect in the stream during the relocation process but can be prevented if carefully done.

Levee Plan

Residences and businesses adjacent to the stream limit the space required for levee construction. Due to this requirement, levee construction would necessitate the removal of sizable timber stands. In some areas, park land would be disrupted. Revegetation of levee could restore some of the original ecosystem; however, some fauna diversity and abundance would be lost.

Detention Pond Plan

The construction of detention ponds would have a minimal impact if sited in non-wooded areas. In areas where erosion predominates and few trees exist, the construction of a detention pond would create desirable settings for park areas. However, if a construction site is located in an ecologically valuable area as discussed earlier, the natural resources will be significantly degraded. Excessive tree removal and rock excavation in sensitive areas would significantly affect fauna.

Channelization

In general, channel plans have the greatest impact on the stream environment. The complete channelization from the headwaters to the mouth of Shoal Creek would adversely impact those valued habitats along the stream. Excessive timber removal and the destruction of geologic points of interest should be avoided if implemented. Excavation and channel paving may disrupt seep and spring flows which support ferns, mosses, and other unique flora along the stream. The removal of limestone cliffs and ponds at scenic locations would further impair the aesthetic setting and should be avoided.

Of the channel plans, the concrete-lined channel has the greatest detriment to riparian habitat. Grass-lined channel plans would allow limited revegetation after clearing excavation. Natural rock channels may have a similar appearance to the original conditions within Shoal Creek, but rock excavation may affect spring or seep flows. However, concrete-lined channels themselves retain little of natural environment except in the undisturbed overbank areas.

Complete channelization of the creek within Austin would probably destroy two key historical points of interest. One is Seider Springs and the other is the Franz Fiset Dam. Other recorded cultural sites along Shoal Creek discussed previously could also be affected by extensive channelization.

Tunnel Plan

When conditions permit, diversion plans are also effective ways to alleviate flood problems. From initial inspection, a typical channel diversion is not feasible due to the high urban structural density surrounding the stream. However, a tunnel plan to divert floodflows from Shoal Creek to Lake Austin is another promising alternative. USFWS, in a planning aid letter dated June 11, 1984 (see exhibit 2), identified tunneling as the least damaging measure when comparing it with channelization and bank stabilization by gabion blankets. As construction activities are redirected toward a new watershed, new environmental considerations are required. On Shoal Creek itself, tunnel construction would be only significant if the ground entry site is located at or near any important cultural, scenic, or ecological area. Tunnel construction would affect more than the geological and ecological features of the Shoal Creek watershed alone. Water quality effects on receiving lakes and ground water and environmental effects associated with tunnel placement are important considerations.

As discussed earlier, Shoal Creek carries heavy concentrations of pollutants in urban runoff. By proper inlet tunnel design (weir structure or elevated inlet), pollutant-laden low flows would continue to pass downstream to Town Lake, and only diluted high overflow waters would be diverted to Lake Austin. Waters diverted to Lake Austin should not be composed of significant contaminant concentrations to alter lake quality. Stormwaters exfiltrating the tunnel should not be of significant quantity to affect or alter the ground water quality, nor should infiltrating ground waters significantly affect Lake Austin. Furthermore, this leakage or infiltration can be minimized by lining the tunnel.

Natural springs adjacent to Lake Austin provide a minor but continuous source of water. They also are aesthetic and cultural points of interest. Disruption of springflows would adversely impact the environmental setting. Therefore, it is necessary to assess any project impacts on natural springs. The tunnel should not disrupt springflows if properly constructed and sited. Boring techniques rather than explosive techniques would better prevent the collapse of possible underground caverns that direct flows to these springs. The tunnel outlet should also be located away from spring areas (particularly Taylor, Mount Bonnell, and Powerhouse Springs) and cultural points of interest.

COMPARATIVE IMPACTS OF SPECIFIC ALTERNATIVES

Several specific alternatives were further investigated in detail. One included was a no action plan. The structural plans are grouped into two basic types of flood protection improvements: the channel type and the tunnel-channel combination type.

Initially three channel plans were considered. Each was composed of two 11-foot conduits under Highway 183 and an improved 50-foot bottom width channel above Highway 183 extending to the MOPAC Railroad. Downstream of Highway 183 to Town Lake, the three plans differ in channel size. The minimum channel plan consists of a bottom width that varies

from 20 to 90 feet. The intermediate channel plan also has a maximum both width of 90 feet in some areas, but maintains at least a 35-foot bottom width throughout the reach. The maximum channel plan has a bottom width that varies from 45 to 90 feet. As discussed previously, channelization as outlined in any of these three plans would have adverse affects on the environment. The maximum channel plan would have the greatest overall impact of all six alternatives considered. With all three channel plans, cultural sites and historic points of interest would be difficult to preserve in place. Valuable wildlife habitats between Northland Drive and the projected position of 9th Street will become significantly affected if excessive riparian woods are removed. Aquatic life resident in shallow pools and the small reservoir will be significantly degraded if the pools are not retained after channel construction. In the downstream third of Shoal Creek, the recreational value of park areas and hike/bike trails will also be affected if trail relocations accompanied with excessive tree removal becomes extensive. Furthermore, the excavation of limestone rock may affect the aesthetic appeal of rock cliff areas. No significant or permanent water quality impacts are expected to occur with the three channelization plans. During channel construction, stream turbidity should temporarily increase; however, the stream water should return very near to its former water quality state.

USFWS identified that the minimum, intermediate, and maximum channel plans would result in the loss of 174, 176, and 195 (all) acres of riparian habitat, respectively (see exhibit 3). Based on these values, USFWS further projected that fish and wildlife resource losses would vary from 94 percent for the minimum full-length channel plan to 100 percent for the maximum full-length channel (see exhibit 4).

Initially, three combination tunnel/channel plans were considered further. These plans and later plans consist of two 11-foot conduits under Highway 183 and an improved 50-foot bottom width channel above Highway 183 extending under MOPAC Railroad. The initial three combination plans consist of an intermediate channel improvement with 35-50 foot bottom width which extends from Highway 183 to Northwest Park and a short channel improvement on Hancock Creek (Shoal Creek tributary) upstream of a tunnel inlet. The short channel improvement is approximately 700 feet of 30-foot bottom width, grass-lined trapezoidal channel with a concrete drop structure and stilling basin at the upper end of the channel. The three combination plans differ in tunnel sizes with diameters of 10, 18.5, and 23 feet. All of initial plans would have diverted high Shoal Creek flows through a tunnel inlet at Northwest Park to Lake Austin. All of the early combination plans also included a separate tunnel system that would divert flows from the Hancock Creek channel improvement. The early plans having 18.5- and 23-foot diameter tunnels also included a Shoal Creek intake at 45th Street on the same tunnel system diverting flows from Hancock Creek. Other intake locations later considered were locations at 24th Street and 19th Streets.

All tunnel outlet structures of initial plans were originally located on Lake Austin near areas of public concern: Huck's Slough area near to the municipal raw water supply intake and Laguna Gloria Art Museum and the Dry Creek area near lakeside residences. After further public involvement

and coordination with the city, 14-foot and 16-foot diameter tunnel plans were also considered. Tunnel outlet areas were relocated to areas of lesser concern: one outlet on Lake Austin near the Bull Creek confluence and one outlet on Town Lake near Pressler Street.

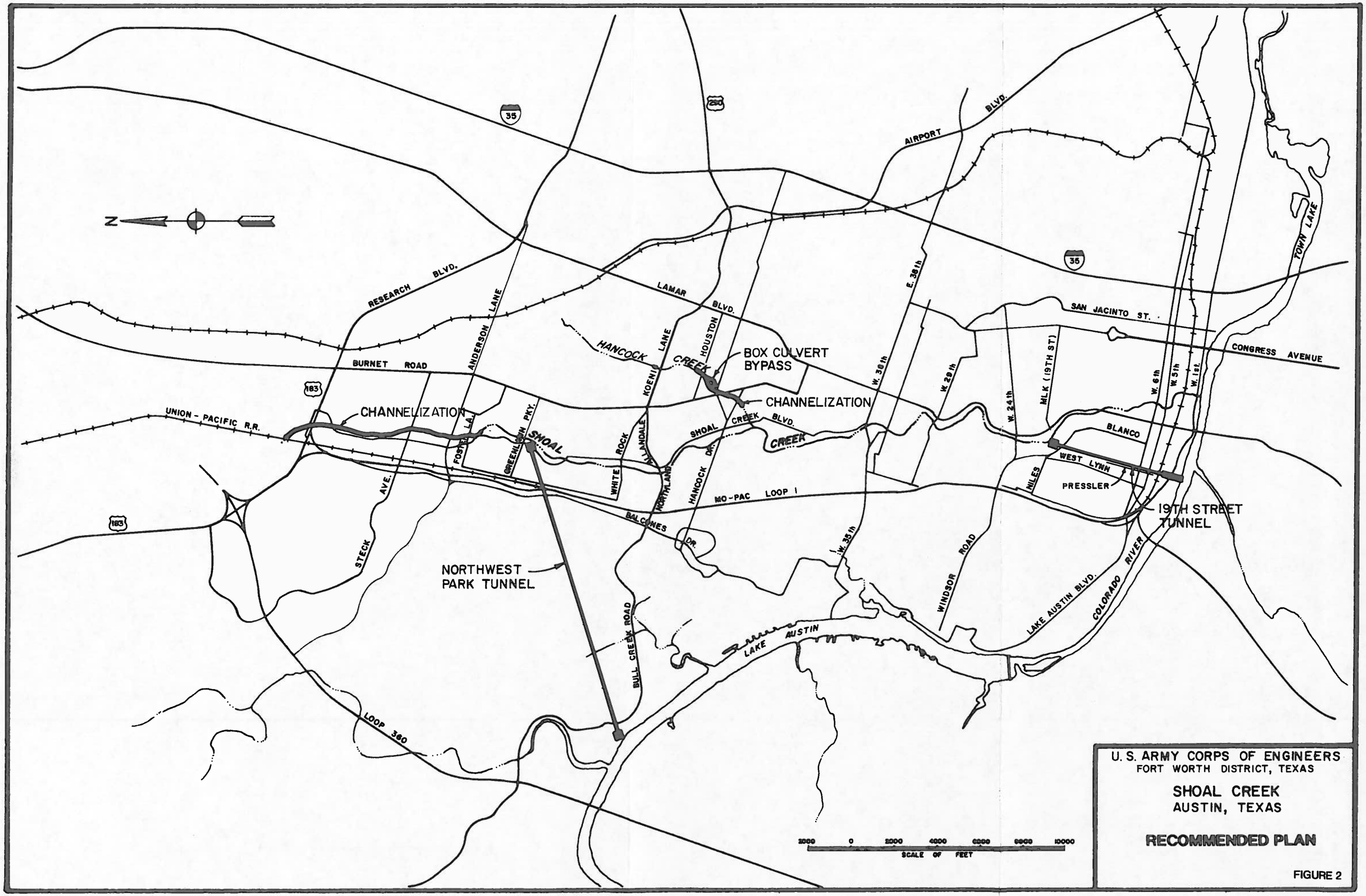
All of the earlier tunnel/channel combination plans have similar environmental effects. The early 23-foot diameter tunnel plan would have the greatest impact of the combination plans. However, with regard to environmental affects, this plan differed very little from the early 18.5-foot diameter tunnel plan. The 10-foot diameter tunnel plan having only one inlet in the Hancock Creek and one inlet on Shoal Creek had the least habitat impact among the early tunnel/channel combination alternatives. All channelization included in these and later combination plans are situated in areas of relatively low ecological, cultural, and aesthetic value. Tunnel inlet construction will disrupt a relatively small stream area compared to channelization in the lower reaches of Shoal Creek. USFWS depicted the relative low adverse affect on the existing habitat quality with the combination plans versus the other channel plans in table 1 of their letter dated October 1, 1985 (see exhibit 3). Therefore, environmental impacts on Shoal Creek are considerably less with the tunnel-channel plans than the extensive and complete channelization of Shoal Creek.

However, some of the potential environmental impacts are transferred from Shoal Creek to the Lake Austin area. The combination plans having the same outlet locations would similarly impact the environments near the tunnel outlets. Due to the tunnel outlet locations on Lake Austin, the early plans would potentially impact the aesthetics on adjacent residences and lake water quality. However, the later plans included only one outlet on Lake Austin and have other features that would incur less impacts on water quality and lakeside residences. In the following discussion, the recommended plan which is a 14-foot diameter tunnel/channel combination plan is further detailed.

ENVIRONMENTAL ASSESSMENT OF THE RECOMMENDED PLAN

GENERAL

Based on economic and hydraulic feasibility, the 14.0-foot diameter combination tunnel/channel plan alternative was selected for implementation (see figure 2). This plan will have a 14-foot tunnel diversion at Northwest Park and a 14-foot diversion at 19th Street. It also includes approximately 8,800 feet of channelization in the upper reaches of Shoal Creek and 3,200 feet of channelization along Hancock Creek. Associated environmental impacts are discussed in the following paragraphs.



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

SHOAL CREEK
AUSTIN, TEXAS

RECOMMENDED PLAN

FIGURE 2

WILDLIFE

Overall, this plan probably has the least impact on riparian woods and wildlife. The tunnel to Lake Austin will open through a cliff area and the connecting still basin and short channel to Lake Austin lie in cultivated field area. Few trees are present in this immediate cliff/field area, while abundant large wooded stands reside above on the cliff. Therefore, tree removal will be very few minor and insignificant near Lake Austin. A few more trees will be removed in the construction of the tunnel outlet on Town Lake, but effects on existing habitat there will be relatively insignificant. Tree removal in outlet areas is not nearly as significant as tree removal associated with the other option of channelization in the lower reaches of Shoal Creek where forest areas are encompassed by densely urbanized areas.

In the Recommended Plan, the channelized portions are limited to upstream areas relatively low in wooded habitat. The area north of Highway 183 and downstream of the MOPAC Railroad bridge is primarily vegetated with tall grasses and very few trees. The area below Highway 183 to Forest Lane is highly urbanized. A few scattered trees lie near the channel, but commercial parking lots and residential backyards closely border the stream. Therefore, the upstream channelization of the recommended plan will have no significant affects on wildlife.

Furthermore, trees lost to project activities will be replaced according to the city's tree replacement program. Some of the trees lost can be replaced with tree planting along the channelized portion of the project.

AQUATIC LIFE

As discussed previously, significant aquatic life in the upper portions of Shoal Creek is not generally present, and practically no fish reside in the proposed channelized portion of the Recommended Plan. In the upper reaches above Northwest Park, frogs, toads, and other amphibians may reside in the areas where soil depth allows. Habitats for these water-associated organisms may be disrupted during channel construction but should return after the channel is completed.

In downstream areas of Shoal Creek where significant aquatic life exists, the Recommended Plan should not significantly affect aquatic life. Construction activities in these areas will be limited to tunnel inlet and diversion construction and will not require extensive alterations to the streambed. Existing aquatic habitats along the streambed in the downstream reaches will not be destroyed or displaced with the Recommended Plan as with a comprehensive channel alternative. Construction activities of both the tunnel inlets and upstream channel may cause temporary turbidity problems for downstream aquatic life. USFWS had expressed a concern with downstream flows in the letter dated October 1, 1985 (see exhibit 3), and recommended the passage of the 1-year flow frequency event down Shoal Creek. As a result of this concern by USFWS, instream conduits were enlarged so that sufficient flows are passed downstream to maintain

and to frequently flush small water pools and small ripples. Therefore, fish and other aquatic life will not be significantly affected.

CULTURAL RESOURCES

At the present state of knowledge, no recorded cultural resources will be impacted by the Recommended Plan. However, as appendix B notes, the identification search for cultural resource evidence remains incomplete. It is provisionally suggested that the proposed tunnel outlets will be verified as not having significant cultural resources, and that the proposed tunnel outlets are sound choices in terms of impacting areas where cultural resources are unlikely. Also, a portion of historic Pease Park will be impacted by the proposed 19th Street tunnel inlet. Field and archival search remains to be done in terms of this specific location, and any cultural resource evidence identified here will require evaluation and, if found to be significant, mitigation. The issue of secondary impacts from tunnel spoils deposition, haul roads, and other broader construction activities has been investigated. A May 1990 reconnaissance of the disposal sites identified by the city of Austin did not reveal any evidence of cultural resources. These sites, located near southeast Austin are either fully permitted for receiving such material, or are suited for permitting. No cultural resources were observed in the site visit. It is anticipated that sufficient flexibility in planning will permit these and other similar actions to be directed to areas where no cultural resources exist. Any emergency discoveries of cultural resources shall be treated as they occur. In such situations, construction shall stop until a Corps archeologist can be notified and subsequent treatment implemented. Consultation under provisions of the National Historic Preservation Act of 1966, as amended, have been initiated (see exhibits 7-9) and will continue as the project proceeds. Any other applicable preservation laws will be followed.

The proposed project may, however, protect existing cultural resources that would otherwise be impacted under the existing conditions. For example, the proposed project will reduce high stormwater flows in the lower reaches of Shoal Creek. Consequently, cultural sites in these areas will be less damaged by erosional forces. Cultural resources in or near construction areas could also be protected in place or otherwise treated instead of undergoing gradual loss through erosion, relic collecting, or other impacts.

RECREATION

Effects to Existing Recreation

The Recommended Plan should not affect the existing hike and bike trail and park system in the lower reaches of Shoal Creek. Whereas, extensive channelization in the lower reaches would adversely affect the recreational resources.

In the Recommended Plan, two tunnel inlets will be in Northwest Park and Pease Park. The tunnel inlets will not cause significant impacts to park activities or aesthetics. Inlets will be designed to be

aesthetically acceptable with low profiles, structural coloring, berming, and adjacent shrub and tree plantings as needed. In Pease Park, one or two goal stands of an existing frisbee course will be moved, but should not significantly affect play.

The 19th Street Tunnel will outlet in Deep Eddy Park. The outlet and channel to Town Lake will split the park into two segments and take approximately 3 acres out of recreation use. According to Texas Parks and Wildlife Department, this portion of Eddy Park was originally purchased with the use of Land and Water Conservation Fund (LWCF) through the National Park Service. Provisions of the Project Agreement for which fund assistance is received states:

"The Participant agrees that the property described in the project agreement and the dated project boundary map, made part of that agreement, is being acquired of developed with Fund assistance, and that it shall not be converted to other than public recreation use but shall be maintained in public perpetuity."

In order to take these lands out of recreation use the city of Austin will need to file for a conversion through the Texas Parks and Wildlife Department to the National Park Service (NPS). NPS has established certain guidelines for converting these lands which the State of Texas must follow. Conversion is strongly discouraged by NPS and there are no guarantees that a request for conversion will be approved.

Exceptions generally occur if it can be shown that proposals to construct public facilities results in a gain or increased benefit to public recreational opportunity. Final review and approval of such cases are made on a case by case basis.

If an exception is not possible, the Texas Parks and Wildlife Department and the National Park Service may consider replacement of lost land with property of equal or greater value and is of reasonably equivalent usefulness and location. Completion of an environmental assessment for substitution of a site is required.

Since the proposed outlet, stilling basin and outlet channel will take three acres of recreational lands out of recreation use, it will be necessary for the city of Austin to try to either replace these recreation lands or demonstrate that the project can be enhanced to provide recreational opportunities.

Due to the NPS requirements described above, the Corps of Engineers and the city of Austin will further explore the following two options during the Design Memorandum phase: (1) construction of the outlet, stilling basin, and channel (see figure 3) and the purchase of replacement lands in the same general area, or (2) construction of the outlet, stilling basin with an enhanced recreational lagoon (see figure 4).

With construction of option (1) the proposed project channel would displace the existing softball field, soccer field, and restroom/concession building. These facilities would be moved west of the

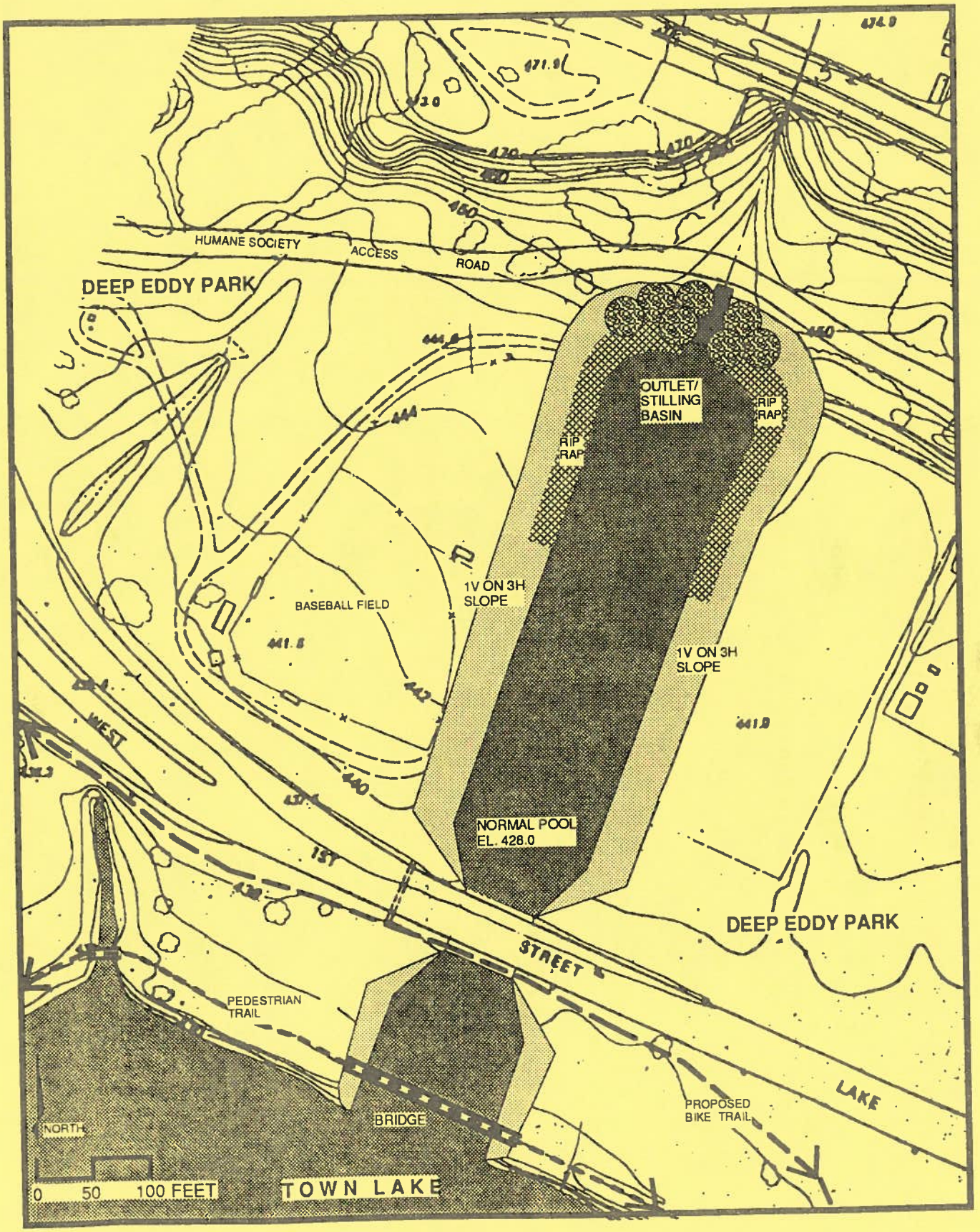
existing fields (see figure 3). Since the soccer field is seldom used, the city of Austin would eliminate this field rather than relocate it. The outlet structure would be located far enough away from the railroad tracks and hillside to allow replacement of the Humane Society access in its present location. A temporary road would be constructed to allow access to the Humane Society during construction of the outlet and stilling basin. The existing Town Lake pedestrian bridge south of West 1st Street will need to be replaced with a 8-foot wide pedestrian bridge to span the widened channel. About 3 acres would be taken out of recreation use with this plan. The cost of replacing this land with land of equal or greater value and usefulness has not been estimated at this time.

With the construction of option (2) the outlet and stilling basin would be located in the same place as option 1. Thus, the access road to the Humane Society and Town Lake trail pedestrian bridge replacement would remain the same as option 1. The outlet channel to Town Lake would be designed to accommodate the same flow but would be modified to allow curved shorelines and a variety of side slopes to maximize public access to the water's edge. Shallow depths to some shoreline areas would allow the establishment of some wetland plants. An additional culvert would be placed north of the proposed channel to increase water circulation within the lagoon and thereby maintain water quality. The West 1st Street bridge would be raised high enough to allow two trails to underpass and allow pedestrian access to Town Lake trail around the lagoon. West 1st Street would be constructed with a 15-foot sidewalk on the south side of to provide access to the future Town Lake bicycle trail. The existing softball field and associated restroom/concession building would be relocated to another part of Deep Eddy Park or to another park in the area. Trees would be planted around the outlet area to shade and soften the hard architectural lines of the outlet structure. If a larger pool is located next to the stilling basin it may be possible to reduce the amount of riprap used around the stilling basin and outlet structure. Color and texture would be added to exposed portions of the outlet structure to reduce the contrast of the outlet structure and better blend with park aesthetics. Fences would be placed around the outlet structure to prevent access to the tunnel.

Also, no significant adverse effects will occur on recreational facilities on Lake Austin. Water quality should not change significantly to impact recreational activities at Lake Austin and Town Lake.

Potential Recreation Development

In the lower reaches, Shoal Creek has an excellent recreation resource in the existing hike and bike trail system. The existing trail is heavily used and connects several park areas. In general, the mid-reaches of Shoal Creek are very aesthetic. Although the manmade trail is not continuous in this area, the rocky channel bed in a large portion of the mid-reaches provides a natural pathway for hikers most of the year. With this natural pathway in place, the city of Austin has an excellent opportunity to provide a continuous hiking trail from the mouth to US Highway 183 and Walnut Creek.



SHOAL CREEK, AUSTIN, TEXAS

FIGURE 3 - RECOMMENDED 19TH STREET OUTLET

SHOAL CREEK, AUSTIN, TEXAS

FIGURE 4 - OPTIONAL LAGOON AT 19TH STREET OUTLET

In the upstream area, the narrow streambed has less rock exposed and is muddy following rains. Therefore, the streambed is not suited for the hiker. Since the proposed channelization lends itself quite readily to an extension of a trail from Foster Lane near Northwest park to Shoal Creek Boulevard, an optional recreational plan was developed. This plan includes a paved hike/bike trail along 1.4 miles of the stream with park benches at potential rest stops (see figures 5 and 6). The proposed 1.4-mile trail will help fill the need for an additional 15.6 miles of hiking/ biking trails needed in the Shoal Creek area by 1995. The recreational costs and benefits of this plan are listed in table 1. Estimates of the use of these facilities were made from per capita participation rates extracted from the 1985 Texas Outdoor Recreation Plan (TORP) for Region 12, the Capitol Area, and population projections developed by the Southwestern Division, US Army Corps of Engineers. According to 1985 TORP facility standards, this 1.4-mile trail can accommodate about 18,900 visitors per mile each year or about 26,460 visitors along the 1.4-mile trail each year. The benefits accruing to this visitation were estimated in accordance with appendix A of ER 1105-2-40, Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. A benefit value of $ 2.90 for each visitor-day will yield a total benefit of $77,000 per year (value per recreation day based on criteria identified in "Procedures for Evaluation of NED Benefits and Costs in Water Resources Planning"). Costs of development were estimated from similar projects and updated to February 1991 price levels. The benefit-to-cost ratio for this plan is 2.6 to 1.0.

TABLE 1

RECREATION PLAN
COST AND BENEFIT SUMMARY
(February 1991 price level)

COST SUMMARY

Item	Cost
Trail Surface, 8 feet wide	$ 73,500
Signs	1,200
Privacy Fencing	37,000
Benches	1,000
Landscaping	37,700
Subtotal	$150,400
Contingencies 25%±	37,600
Subtotal	$188,000
Engineering and Design	16,000
Supervision and Administration	18,000
Total	$222,000

ANNUAL CHARGES

Interest and Amortization (100 years at 8-7/8%)	$20,000
Annual Operation, Maintenance, and Replacements	10,000
Total Annual Charges	30,000

BENEFIT SUMMARY

18,900 Visitors per mile per year x 1.4 miles x $2.90 per visit	$77,000
Benefit-to-Cost Ratio	2.6

Proposed Recreation Plan

The city of Austin Parks and Recreation Department is interested in constructing a trail along the proposed Shoal Creek channelization shown in figures 5 and 6. This is one of several vital links of a larger trail system which will connect the City Lakes Area to the future Walnut Creek 12-mile trail system. The proposed trail will be isolated from the existing Shoal Creek trail system. About 2.5 miles will be needed to link the proposed trail to the northernmost part of the existing Shoal Creek trail. As mentioned earlier, however, one could hike along the 2.5-mile

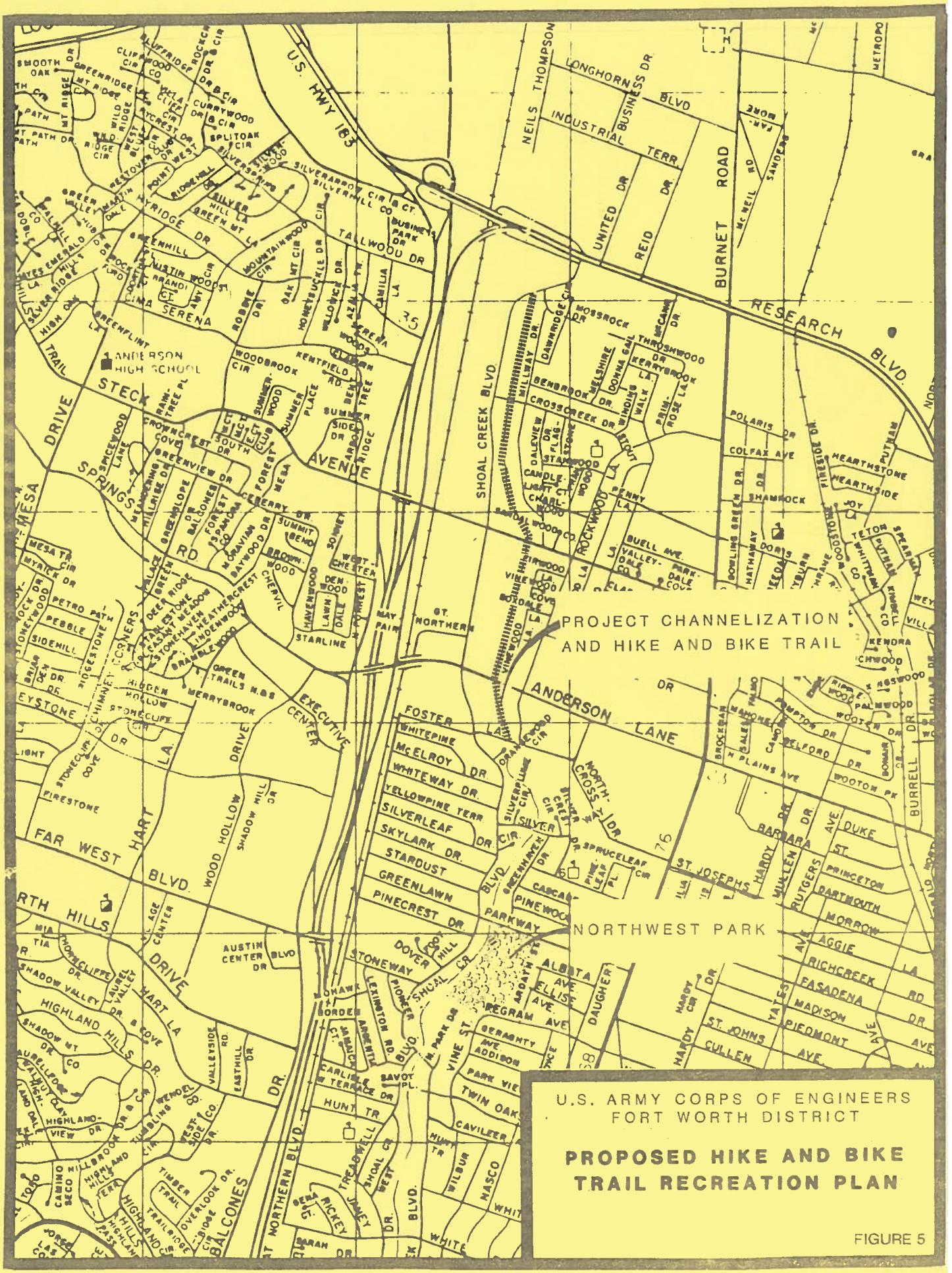
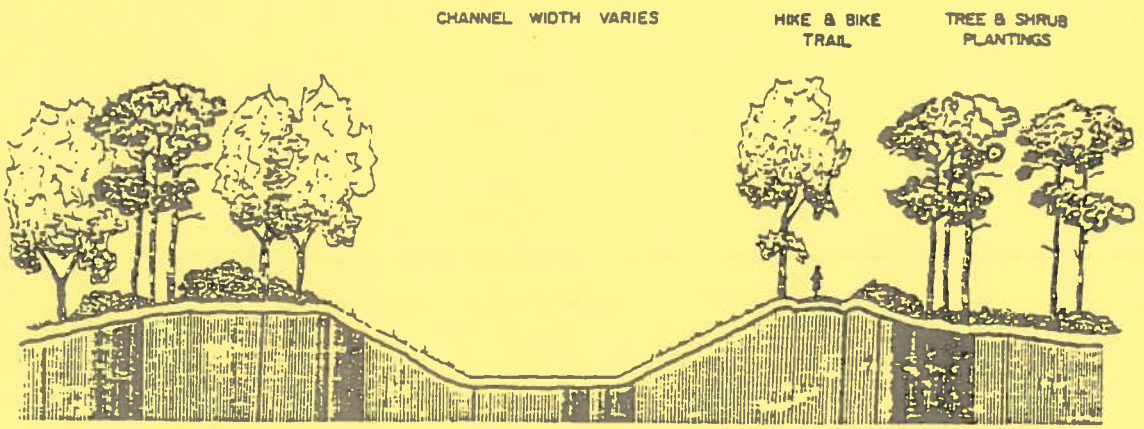
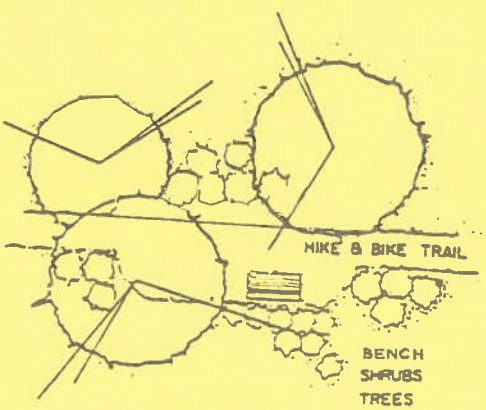

PROJECT CHANNELIZATION
AND HIKE AND BIKE TRAIL
NORTHWEST PARK
U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT
PROPOSED HIKE AND BIKE
TRAIL RECREATION PLAN

FIGURE 5



TYPICAL SECTION

HIKE AND BIKE TRAIL



DETAIL

U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT

PROPOSED HIKE AND BIKE TRAIL RECREATION PLAN CONCEPT

FIGURE 6

rocky bottom segment of Shoal Creek from Seider Springs Park through Northwest Park to the end of the city's recent channel improvements near Foster Lane until a surfaced trail is developed.

The proposed trail would proceed north from the city's recent channel improvements above Northwest Park. A continuous 8-foot wide trail would be constructed from this park to Shoal Creek Boulevard. Except for the initial start and when passing under bridges, the trail would be routed along the side of the channelized creek which affords the most space.

Due to space constraints, it may be necessary to start the trail with a concrete trail connecting with the rock stream bed or the stair-step rock improved channel walls, pass under the bridge at Foster Lane, transition to the upper bank until Anderson Lane, go under Anderson Lane, transition to the upper bank until Steck Avenue, go under Steck Avenue, transition to the upper bank until Crosscreek Drive, and cross Crosscreek Drive since the road is lightly traveled and has a low bridge. If this bridge is replaced with one of more head room, the trail could then be routed underneath. The trail would then proceed along the upper bank until it ends at Shoal Creek Boulevard. In the future, the city may be able to seek a suitable underpasses in the same vicinity which would allow connection to the proposed Walnut Creek trail system north of U.S. Highway 183.

Areas in the channel bottom or ramped portions under bridges will need to be concrete due to erosion potential during high water. If channel capacity allows, the concrete portions under bridges should be placed on a slight shelf so the trail can be utilized even with a small flow in the creek. Some type of rock or concrete stabilization may be necessary above or below these trail segments. The trail portions under bridges would be unusable during high flows.

The city is interested in compacted granite fines for portions of the trail outside the channel since a large number of potential users will be hikers and runners. This will involve more expense, since the city will need to pay for 100 percent cost over and above the 50 percent cost of developing a concrete or asphalt trail. Since residences are located so close to the creek, it may be necessary to install a privacy fence along the back side of those residences bordering the trail. The residential area which will probably need privacy fencing is located between Foster Lane and Anderson Lane.

In addition, signs would be located at each trail-road access point to orient the user to the trail system. Six rest benches would be located at various points along the length of the proposed trail.

The local sponsor has expressed a desire to cost share the recreation facilities, and this plan can be tailored to local desires. The details of the recreation plan may vary slightly, depending upon citizens' review and comments.

WATER QUALITY

The recommended plan may influence the existing water quality of Lake Austin as well as Town Lake and the lower reaches of Shoal Creek. Furthermore, the combination plan may potentially affect the existing water qualities in several ways.

As noted earlier, Lake Austin Watershed is strictly zoned for residential development which prevents excessive urban runoff pollutants from entering the watercourse. Whereas, Town Lake Watershed has a higher density of residential and commercial lots in place. In general, Lake Austin has better water quality than Town Lake. Shoal Creek carries higher concentrations of fecal coliforms, metals, and pesticides than either of the lakes. Furthermore, Shoal Creek flows may be the major source of fecal coliform pollution in Town Lake. However, Town Lake water is used as a domestic water supply with no significant treatment problems.

The initial Recommended Plan was originally designed to allow instream flows of 50 cfs or less to continue to pass by both diversion points to Town Lake downstream and to simultaneously divert those instream flows in excess of 50 cfs to Lake Austin through two 18.5-foot diameter tunnels. Due to public concern, the Corps revised this initial recommended plan. One of the tunnel outlets was removed from Lake Austin and placed on Town Lake. In addition, a smaller tunnels of 14-foot diameter replaced both 18.5-foot diameter tunnels.

Through further review and coordination with city of Austin, the Corps learned that water quality in Lake Austin could be further improved while still maintaining an effective flood control measure on Shoal Creek. Using a simple mass balance computer model, the city of Austin analyzed the effect of diverting pollutant loads of 13 contaminants on Lake Austin. Modeled contaminants consisted of total suspended solids (TSS), biochemical oxygen demand (BOD), nitrates (NO_3), ammonia (NH_3), total kjeldahl nitrogen (TKN), total phosphorus (TP), total organic carbon (TOC), copper (Cu), iron (Fe), lead (Pb), zinc (Zn), arsenic (As), and fecal coliforms. The city of Austin developed a pollutant load increase versus diversion discharge curve and recommended that instream flows in excess of a 1,000 to 1,500 cfs be diverted to Lake Austin. Table 2 shows the effects on Lake Austin for no diversion (existing condition) and diversions of 50 cfs, 500 cfs, 1,000 cfs, and 1,500 cfs under the average annual condition. On worse case monthly basis, more diversions would tend to occur in the month of May or October. Table 3 depicts the projected effects on Lake Austin for the month of October.

TABLE 2

Pollutant Concentrations in Lake Austin Below Bull Creek
under Different Diversion Scenarios
(Average Annual Condition)

Pollutant	With No Diversion	Diversion of Overflow when Shoal Creek Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs
BOD	0.89*	0.91	0.90	0.90	0.89
TSS	37	40	39	38	37
NO_3	0.14	0.14	0.14	0.14	0.14
NH_3	0.046	0.047	0.047	0.047	0.046
TKN	0.68	0.68	0.68	0.68	0.68
TP	0.030	0.033	0.032	0.031	0.030
TOC	4.0	4.0	4.0	4.0	4.0
Cu	1.25	1.26	1.26	1.25	1.25
Fe	13.30	13.40	13.40	13.30	13.30
Pb	1.17	1.18	1.18	1.17	1.17
Zn	6.07	6.07	6.07	6.07	6.07
As	1.00	1.02	1.01	1.00	1.00
Fec. Col.	230	326	290	256	233

* Values shown are annual average pollutant concentrations (including both baseflow and storm-event conditions). The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn, or As is 10^{-3} milligrams per liter. The unit of all other parameters is milligrams per liter.

Source: City of Austin, Environmental Planning Division, "Impacts of the Proposed Shoal Creek Diversions on the Water Quality of Lake Austin and Town Lake", July 1989 (Supplement to June 1988 Report).

TABLE 3

Pollutant Concentrations in Lake Austin Below Bull Creek
under Different Diversion Scenarios
(One of the Worst Cases, the Month of October)

Pollutant	With No Diversion	Diversion of Overflow when Shoal Creek Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs
BOD	1.15*	1.22	1.21	1.17	1.15
TSS	59	74	72	65	59
NO_3	0.148	0.157	0.155	0.151	0.148
NH_3	0.044	0.046	0.045	0.045	0.044
TKN	0.79	0.81	0.80	0.80	0.79
TP	0.039	0.056	0.054	0.046	0.040
TOC	4.8	5.0	4.9	4.9	4.8
Cu	1.35	1.40	1.39	1.37	1.35
Fe	12.3	12.6	12.5	12.4	12.3
Pb	1.17	1.22	1.21	1.19	1.17
Zn	6.0	6.1	6.0	6.0	6.0
As	1.00	1.09	1.07	1.03	1.00
Fec. Col.	394	904	827	582	394

* Values shown are annual average pollutant concentrations (including both baseflow and storm-event conditions). The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn, or As is 10^{-3} milligrams per liter. The unit of all other parameters is milligrams per liter.

Source: City of Austin, Environmental Planning Division, "Impacts of the Proposed Shoal Creek Diversions on the Water Quality of Lake Austin and Town Lake", July 1989 (Supplement to June 1988 Report).

Based on this information, the Corps redesigned the diversion structure at the Northwest Park so that instream flows of 1,000 cfs or less would continue to pass downstream Shoal Creek and only flows in excess of 1,000 cfs would be diverted to Lake Austin. As a result of this revision, average annual diversion spills to Lake Austin would be reduced from approximately 9 or 10 to approximately 1 or 2. With this revision, total annual diversion to Lake Austin would be reduced to approximately 330 acre-feet compared to a previous value greater than 2,500 acre-feet for both tunnels.

As a result of the diverting only the excess streamflow over 1,000 cfs, the average pollutant load or concentration in Lake Austin would increase approximately 1.6 percent with the revised recommended plan. With this case, TSS, TP, and fecal coliforms would specifically increase to 2.7, 3.3, and 11.3 percent, respectively. The existing concentrations of these substances in Lake Austin is generally low, and increases with the plan now recommended will not be significant. On a worse case month basis (October), the pollutant load or concentration would increase approximately 7.1 percent with the revised plan. With this case, TSS, TP, and fecal coliforms would specifically increase to 10, 18, and 48 percent, respectively. However, these specific contaminants are elevated temporarily and changes in average annual concentrations in Lake Austin would be minor.

With the minor pollutant loads from Shoal Creek, the diversions to Lake Austin should not be sufficient to degrade the overall Lake Austin water quality. Furthermore, the tunnel outlet near the Bull Creek confluence on Lake Austin is approximately 2.3 miles upstream of the Davis WTP raw water intake. This distance is much greater than the previous Recommended Plan and allows more time for sediments to settle from the water column before waters reach the nearest water supply intake.

Shoal Creek waters to be diverted to Town Lake will have no significant effects on Town Lake since these waters naturally flow into Town Lake. The raw water intake for the Green WTP is located upstream of the mouth of Shoal Creek and downstream (approximately 0.7 mile) of the proposed tunnel outfall. Raw water in the vicinity of the intake will occasionally be affected by the diversions, but can be easily treated. As a result, the diversions to Town Lake may increase the treatment cost slightly. Ultimately, diverted Shoal Creek waters mixed with Lake Austin waters will once again reach Town Lake through Lake Austin releases.

Stilling basins near tunnel outlets should prevent the occurrence of excessive erosion and significant resuspension of sediments.

It is also important to note that sufficient flows in Shoal Creek are necessary to maintain dissolved oxygen to support aquatic life. Periodic flushing flows through the creek remove biodegradable materials that deplete dissolved oxygen and prevent stagnation. The Recommended Plan will allow sufficient flows to maintain instream aquatic life.

Within the diversion tunnels, some infiltration and exfiltration of ground water is expected to occur. However, since the tunnel is to be

lined, no significant flow quantities are expected to be exchanged through the tunnel walls. Furthermore, Lake Austin receives minor springflows continuously. Boring techniques should not disrupt these springflows that mix with Lake Austin water. The tunnel lining and location will also prevent the infiltration of any underground water.

On Shoal Creek, near and downstream of tunnel inlets and channelization, construction activities will cause dramatic, but temporary, water quality problems. Excavation operations will cause temporary excessive turbidity in downstream reaches and possibly Town Lake. However, proper clean-up and construction techniques can minimize these problems.

Tunnel construction activities could potentially incur the greatest water quality problems but will be insignificant with proper construction techniques to prevent rock material and dust from entering Lake Austin and causing severe turbidity problems. Construction activities on inlets at Northwest Park and Pease Park should cause temporary turbidity problems in Shoal Creek until the diversion areas are cleared of extraneous materials.

Since Lake Austin is used for recreation, it is important to note water quality with respect to swimming and bathing. Waters to be diverted at Northwest Park are much cleaner than waters sampled downstream at West 12th Street. Fecal coliform bacteria concentrations in diversion waters are not expected to be as elevated as those sampled at West 12th Street where there is a greater opportunity for older downtown sewers to leak and extensive pavements to transport pollutants to Shoal Creek. Furthermore, diversions from Northwest Park would be relatively infrequent (approximately 1 to 2 times a year) and temporary. As a result, fecal coliform concentrations would be slightly elevated in Lake Austin for a relatively short duration. This condition would not pose a significant health risk to swimmers and bathers. Therefore, the proposed project would not significantly affect the recreational water quality of Lake Austin.

To further optimize the quality of divisions, the channel upstream of the tunnel inlets should be kept clean. Adjacent sanitary sewers to the channel should be checked and resealed, if necessary, to prevent bacterial or other pollutant contamination of Lake Austin.

In a previous letter dated August 4, 1987, the Texas Water Commission concurred with the Finding of No Significant Impact for the earlier Recommended Plan that consisted of two tunnel outlets on Lake Austin, but recommended the Corps consider incorporating a water quality sampling program as part of the overall flood management plan. However, the Recommended Plan has significantly improved with revision. Flow volume and frequency of diversion from Shoal Creek have been drastically reduced. With the improved features of the revised recommended plan, the Corps considers that a water quality sampling station for diversion design and operations is not needed.

Based on all the above considerations, water quality in the study area will not be significantly affected.

LAKE AUSTIN RELEASE OPERATIONS

The periodic diversion of high flows from Shoal Creek will affect water release operations of Lake Austin and possibly Lake Travis. If diversion flows are accounted for, no major problems should occur in the release operations to control the water elevation for Lake Austin. If the water elevation rises above bank due to sudden arrival of diversion waters, lakeside residences or property may be damaged. However, if the upper watershed of Shoal Creek is monitored for its hydrological condition as other inflows to Lake Austin, water level can be controlled, and any potential damage can be avoided.

The Lower Colorado River Authority (LCRA) has one employee on site at all times. Additional operational personnel (to be able to operate two sets of gate hoists) are called in based on rainfall or flow forecasts for the Colorado River Basin. The LCRA operates the lake to keep the pool elevation near the normal pool elevation. According to the rating curves for the gates, the LCRA will have sufficient lead time to open the gates needed to pass the diverted flows from Shoal Creek and keep the pool elevation stable. Also, the probability of a critically centered storm occurring on the Colorado River Basin above or below Marshall Ford Dam and a critically centered storm occurring on Shoal Creek at the same time is remote. Therefore, the effects of the diversions on Lake Austin are negligible.

DISPOSAL SITES

The city of Austin has identified a couple of disposal sites for the material excavated from the project. These sites are located near southeast Austin. One site is a dry gravel pit which would be more than sufficient for the material. This site is located near the intersection of FM 973 and Harold Green Road. Another site is located in the same general vicinity. The area is open land, located about 1.5 miles west of U.S. Highway 183 and just south of the Colorado River near a mobile home park. This site is primarily vegetated with common forbs and grasses. Both sites are of relatively low environmental significance above waters of the United States. There are several other gravel pits in southeast Austin and west of Austin which may be available for use as disposal sites when construction begins. No problems are anticipated with disposal of the excavated waste materials. Approximately 45 acres will be needed for disposal of the material.

HAZARDOUS WASTE SITES

There are no known hazardous wastes in the vicinity of any of the proposed construction sites, although extensive investigations have not taken place. If a site is discovered during construction, activities will be stopped until the hazardous waste material is properly contained and disposed of properly.

AIR AND NOISE POLLUTION

Residents near the proposed construction sites will experience temporary disturbances due to the operation of heavy machinery and vehicles. During construction activities, noise levels and air pollution will elevate. Excavation activities will introduce dust and exhaust particulates into the air. Loud compressors, pumps, and other noisy equipment will operate near excavation sites. However, these disturbances will be temporary and limited to working hours. No long-lasting adverse effects are expected to occur.

FISH AND WILDLIFE MITIGATION

The recommended plan has been extensively coordinated with U.S. Fish and Wildlife Service (see environmental exhibits 1 through 5). (Refer back to previous discussion that documented some of their earlier concerns with comprehensive channel alternatives that remove a significant portion of existing bottomland hardwoods.) Since the Recommended Plan incorporates design features which avoid or significantly reduce impacts to fish and wildlife resources, USFWS has deemed no additional mitigation necessary (see exhibit 4). In a letter dated September 25, 1989, USFWS has indicated that the amended changes of the Recommended Plan will not result in significant impacts to fish and wildlife resources (see exhibit 5).

IMPACT SUMMARY OF RECOMMENDED PLAN

In summation, the Recommended Plan will not significantly impact the affected environments of Shoal Creek or areas near Lake Austin. On Shoal Creek, the proposed plan has substantially less overall adverse impacts on riparian forests than any of the comprehensive channel plans. Prime forested areas along Shoal Creek are avoided with the Recommended Plan that would be potentially destroyed with the larger comprehensive channel plans. Although turbidity may temporarily rise downstream of construction sites, aquatic life within Shoal Creek should not be significantly impacted. In comparison to the comprehensive channel plans, the Recommended Plan will also have substantially less adverse impacts to resident aquatic life within Shoal Creek. Furthermore, the Recommended Plan will have less adverse impacts to Shoal Creek esthetics than the comprehensive channel plans.

Although Lake Austin watershed is also affected by the Recommended Plan, no serious temporary adverse impacts or no significant permanent effects should occur. At the Lake Austin outfall site, a relatively small vegetative area at the foot of the cliff will be cleared and the channel will run through a field previously disturbed by cultivation to Lake Austin. Construction methods used will prevent construction materials from entering the two lakes during construction. Temporary turbidity problems may occur in near outfall construction, but no serious effects are expected. After construction, diverted waters from Shoal Creek will on occasion introduce phosphorus and other nutrients, suspended materials, dissolved solids, and traces of pesticides. However, the quality of these materials should not significantly alter the lake water quality. Since

the 19th Tunnel discharges about 3/4 mile upstream of the raw water intake for Green Water Treatment Plant on Town Lake, there may occasionally be a slight increase in chemical dosage but there will not be a significant increase in treatment cost. Northwest Park Tunnel diversions on Lake Austin are relatively better in water quality and further upstream of the two raw water intakes for Ullrich and Davis Water Treatment Plants on Lake Austin. Raw water from Lake Austin will need not any additional treatment after diversions. The potable water supply will not be significantly affected with the diversions and will remain safe for public consumption. Although a slight increase in algal blooms may occur, Lake Austin aquatic life should not be significantly affected. To protect lakeside properties on Lake Austin, it will also be necessary that lake release operations include diversion waters from Shoal Creek in addition to the existing watershed conditions.

In general, construction activities will temporarily annoy local residents with elevated noise and air pollution. Noise and air conditions will return to normal soon after construction is completed.

Excavated material from the tunnels and the channel construction will be disposed in areas above the normal high water mark of any waters of the United States and would be located in areas of low environmental value.

A Section 404(b)(1) evaluation has been completed and is included as exhibit 6 of Environmental Exhibits.

At the various construction sites, historical or cultural resources will be treated under provisions of the National Historical Preservation Act, as amended.

Since the Recommended Plan includes design features that avoid significant, or have minimal, environmental impacts to fish and wildlife resources; no mitigation is necessary.

As a result of this assessment, a draft "Finding of No Significant Impact" for the Recommended Plan has been completed and is included at the beginning of this assessment.

PUBLIC INVOLVEMENT

PUBLIC INVOLVEMENT PROGRAM

Public involvement in the planning of this project includes a Notice of Study Initiation which was sent to applicable Federal and State agencies and city officials. On October 28, 1986, in Austin, Texas, planners from the Fort Worth District, U.S. Army Corps of Engineers, met with city officials and several local interest group representatives to discuss the final array of alternatives adjacent to Shoal Creek. At this meeting, neighborhood representatives adjacent to Shoal Creek favored alternatives that required less removal of vegetation along Shoal Creek. Of the alternatives presented, the neighborhood representatives generally

preferred the tunnel/channel combination plans over the extensive channel plans on Shoal Creek.

On June 23, 1987, Public Notice of the findings of this study was sent to Federal and State legislative representatives and agencies, city officials, adjacent residential owners, and environmental groups for a 30-day comment period. A public meeting has held in Austin, Texas, on August 12, 1987. The public comment period was extended to include any additional written comments stimulated from the public meeting. In the public meeting and subsequent written comments received from local residents and city officials afterwards, several major concerns were expressed. Most of these concerns centered on the high project cost, location of tunnel outlets on Lake Austin, and potential water quality impacts on Lake Austin.

Due to these concerns, the Corps re-evaluated the earlier recommended plan and considered modifications. On October 27, 1987, Corps representatives addressed the city council with several additional plans for further consideration. Instead having two tunnel outlets on Lake Austin, the Corps considered having one outlet on Lake Austin and one outlet on Town Lake. The outlet on Lake Austin was relocated to a place away from residences, known historic resources, and Laguna Gloria Art Center. Based on a city water quality/flow rate analysis, the diversion structure in Northwest Park and Northwest Park Tunnel were redesigned to divert fewer and less frequent flows to Lake Austin.

Another Public Notice of the findings of the study will be sent to Federal and State legislative representatives and agencies, city officials, adjacent residential owners, and environmental groups for a 30-day comment period. A public meeting will be held in mid 1990. A draft copy of the Public Notice is included in this assessment as exhibit 10.

REQUIRED COORDINATION

A copy of the preliminary Environmental Assessment was forwarded earlier to concerned State and Federal agencies for their review and comment. Coordination under the provisions of the Fish and Wildlife Coordination Act was conducted during the planning process and a final Section 2(b) Coordination Act Report prepared by the USFWS is included in the Environmental Exhibits (exhibit 4). An early USFWS survey letter and a planning aid information letter are also included in Environmental Exhibits. A letter of concurrence from Texas Parks and Wildlife Department is also attached to the Section 2(b) Coordination Act Report.

In early stages of the study, the Corps has involved USFWS in the planning process by close coordination through letter and telephone correspondence and through monthly study team meetings. In brief, here are the basic USFWS concerns documented during various stages of the study:

a. In planning letter dated June 15, 1983, USFWS identified the need to preserve the natural areas of high ecological and recreational

values along Shoal Creek and considered adverse impacts to these areas unacceptable (see exhibit 1).

b. In planning aid information letter dated June 11, 1984, USFWS preliminarily identified the adverse impacts of two basic structural alternatives, an extensive channel plan and a tunnel plan (see exhibit 2). USFWS stated in this letter and subsequent documentation that extensive channelization would disrupt existing vegetation, be detrimental to urban wildlife, and have the greater adverse affect than the tunnel alternative.

c. In the same letter, USFWS also stated their concern for the suitable containment and disposal of excavated material from the tunnel borings.

d. In planning aid information letter dated October 1, 1985, USFWS added that the diversion structures near the inlet areas should allow more flows to pass downstream to maintain the existing flushing action for stream quality (see exhibit 3). As a result, they requested that the 36-inch conduit in the diversion structure be enlarged to 42 inches to allow the passage of normal flows and some higher-than-normal flows that will not be diverted into the tunnel.

In response to these USFWS concerns, the Corps has incorporated the following respective items into the Recommended Plan:

a. The Corps concurs that there are high ecological and recreational values along the stream. The natural environment of Shoal Creek is especially important within the urban setting of Austin, Texas.

b. In plan formulation, the Corps has developed a plan which not only provides a high level of flood protection but also avoids the excessive removal of valued habitat. The tunnel systems are predominate flood protection features of the Recommended Plan. Though the Recommended Plan includes a channel, the channel is relatively short and is not located in the more environmentally valued areas of the stream.

c. Tunnel construction activities will include spoil containment measures near the inlet areas (Shoal Creek) and outlets (on Lake Austin and Town Lake) to prevent any serious water quality problems. The sponsor will be required to select a suitable disposal site for excavated material that is above the normal high water mark of any waters of the United States and not located in any areas of valuable environmental resources.

d. As requested by USFWS, the Corps enlarged the 36-inch conduit on the diversion structure to a 42-inch diameter in the Recommended Plan.

After reviewing the preliminary Recommended Plan, USFWS recommended the plan in the Section 2(b) Coordination Act Report and further stated that no additional mitigation is deemed necessary, because this alternate incorporates design features which avoid or significantly reduce impacts to fish and wildlife resources (see exhibit 4). The USFWS has been kept abreast of the revisions in the recommended plan and has indicated through

a letter dated September 25, 1989, that such modifications will not result in significant impacts to fish and wildlife resources (see exhibit 5).

In addition, U.S. Environmental Protection Agency has been notified of revisions to the earlier recommended plan and has provided correspondence which is included as exhibit 11. They will be sent the Environmental Assessment for additional comments.

Correspondence with the appropriate cultural resource authorities has taken place and is included as exhibits to this section of the report and will continue as required by Section 106 of the National Historic Preservation Act.

As noted earlier, a Section 404(b)(1) evaluation has been completed and will be transmitted to the Texas Water Commission for State water quality certification (see exhibit 6).

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

June 15, 1983

Colonel Theodore G. Stroup
District Engineer
Corps of Engineers, U.S. Army
P.O. Box 17300
Fort Worth, TX 76102

Dear Colonel Stroup:

This letter provides our planning input for the Shoal Creek General Investigation Study. It has been prepared in accordance with the Fiscal Year 83 Letter of Agreement and Scope of Work between our respective agencies, and does not constitute a report of the Secretary of the Interior within the meaning of Subsection 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). Our studies have been coordinated with the Texas Parks and Wildlife Department (TPWD).

In February of this year, representatives of both our agencies and the TPWD conducted a reconnaissance field investigation of the Shoal Creek area. Prior to the field survey, the above representatives met with personnel of the Austin Parks and Recreation Department to gather informational data. A literature search to identify additional data on Shoal Creek was also conducted. As a result of this field investigation, it was determined that the Shoal Creek Flood Control Project Area contains wildlife habitat of low, medium, and high value.

DESCRIPTION OF THE STUDY AREA

Shoal Creek, a tributary of the Colorado River, is located in the west central part of the City of Austin, Texas (plate 1). Most of the creek is bordered by residential, commercial, industrial, and parkland areas.

The project area consists of limestone hills which provide rapid storm water runoff and subsequent high flows with excessive velocities. These flows empty into Town Lake south of the central business district. Drainage area of the Shoal Creek watershed is approximately 13.6 square miles. The creek is intermittent with numerous permanent stretches of water. The upper reaches of the creek are mostly dry except after rains. In order to identify and describe the importance of the project area from a fish and wildlife standpoint, we have divided it into segments. Each of these segments is considered in the following discussion.

Shoal Creek from Town Lake on the Colorado River to 12th Street is almost completely surrounded by commercial and residential development. Wildlife habitat is almost non-existent and the fisheries habitat is of low quality. Buildings and factories have encroached almost to the creek bank edges. Outfall structures and railroad trestles and bridges are also present. The creek is also adversely impacted by the quantity and quality of urban storm water runoff which it receives.

Stream banks are mostly alluvial soils with occasional rocky cliffs. Excessive erosion has occurred in places. Retaining walls of concrete, rock, or wood have been constructed in several places. The vegetation is a thin, discontinuous strip immediately adjacent to the creek. Scattered trees include sugarberry, mulberry, live oak, and elm. Some chinaberry, ash, and pecan are intermixed. Grasses, along with other herbaceous species, occur in the creek bed and along the banks. Trash litters the creek bed along much of this section.

From 15th Street north to 29th Street is Pease Park and Shoal Creek Greenbelt. This intensively used urban greenbelt area contains approximately 80 acres of heavily wooded, important wildlife habitat. This is also the site of the first public hike and bike trail in the United States.

Between 29th and 34th Streets, the creek cuts through a low, narrow canyon with heavy vegetation along both banks. High cliffs rise on the west side with mosses and ferns growing along seeps. The creek is wide and rocky with little erosion apparent. Residential lots extend to the edges of the high cliffs on the west side and almost to the waters edge along portions of the gentler slopes on the east side past the bend.

The Scarbrough Bluff area is located at approximately the 3000 block on Shoal Creek. This heavily wooded, rugged terrain is virtually a hidden wilderness in the city. This area is very popular for trail users and university classes.

The Bryker Woods Greenbelt area occurs at approximately the 3100 block north to 34th Street. A direct relationship exists between Bryker Woods Greenbelt and Seider Springs Park which is immediately to the north on the trail linkage. Included in this tract are 7.5 acres of large live oaks and pecan trees. Bryker Woods Greenbelt serves as an outdoor education center to an adjacent elementary school. The Austin Parks and Recreation Department is in the process of extensively revegetating the entire greenbelt with native plants.

From 34th to 38th Streets, Shoal Creek is highly impacted by commercial development and roadway construction. Most of the understory has been removed, with only a few oaks and willows remaining. Creek banks are bare or covered with grass. One high quality area in this reach is Seider Springs Park. This 5 acre urban park has an existing natural spring and is wooded with very large live oaks. Flooding has required some gabion bank stabilization in this locale.

From 38th Street to the State School property, is the Jefferson Street reach. This area suffered the most residential damage in the 1981 flood. Residences have been bought by the city which has a scheduled channel project. Revegetation plans by the Parks and Recreation Department will make it a significant natural greenbelt extension.

North of 38th Street, midway to 45th Street, the creek is bordered by commercial and wooded residential lots on the west and mostly wooded open space on the east to Shoal Creek Boulevard. Tree cover consists of oaks and willows. Continuing to 45th Street, the west bank consists of undeveloped land, mostly cleared except for trees along the creek bank. The terrain around the Texas Records Building on the east bank is sparsely wooded. The creek is rocky, relatively undisturbed, and tree-lined through most of this stretch.

Occurring upstream is the Austin State School natural area consisting of approximately 20 acres of undeveloped creekside meadow and woodland. This area is cited by the Audubon Society as an important wildlife habitat in Austin. The area extends from approximately the 4200 block to 45th Street on both sides of the creek. A greenbelt trail extension has been proposed for this tract.

Between 45th and 49th Streets, the creek is rocky and intermittent with a broad flood plain north of 45th, narrowing around the first bend as limestone cliffs rise on the south side and residential lots encroach on the north. Limestone cliffs (20 ft. high or more) continue around the second bend on the east side. A deep pool lies downstream of a dam at 49th Street which stretches between limestone cliffs on either side. Heavily wooded banks create valuable urban wildlife habitat.

The dam creates a small reservoir which narrows to a rocky flowing creek at Hancock Drive. Above Hancock is a broad flood plain which progressively narrows toward Northland Drive. Limestone cliffs rise on the east in a narrow corridor with more gradually sloping terrain on the west. Austin Memorial Park Cemetery forms a natural forested area on the west side for half the distance between Hancock and Northland. The east side along this stretch is undeveloped west of Shoal Creek Boulevard.

From Northland Drive to Anderson Lane, the creek is narrow with residential lots encroaching. The terrain is rather flat and erosion of the creek banks is evident along much of this stretch. Concrete and/or rocks have been used in some areas to retard erosion. Creek banks are mostly mowed grasses with large trees providing almost complete shade. Willow is invading in some sections.

A 4-acre tract adjoining the Austin Memorial Park Cemetery and Northwest Recreation Center site provides a valuable urban greenspace in a highly developed residential area. This site is heavily wooded with live oak and elms, and is used by hikers and nature walkers. The area has been proposed as part of the Shoal Creek greenbelt trail extension. This

Shoal Creek greenbelt area at Northland Drive serves as important urban wildlife habitat for fish, birds, and small mammals.

Farther up Shoal Creek is Northwest District Park, a heavily used 31 acre park with Shoal Creek on its western boundary. In addition to primary recreation facilities, this park has a wooded natural area and a duck pond.

At the lower end of Northwest Park, a thin strip of thick vegetation lines the western creek banks. American elm, sugarberry, live oak, and eastern red cedar are the dominant species. Above this small area, channel modification is obvious, and the creekside vegetation is grass, scattered trees, and weed species.

From Whiterock Drive to Highway 183, the creek has been rectified. No representative stands of native vegetation exist in this stretch. Streambank vegetation is mostly mowed grasses with some invading willow and cattail. The land bordering the creek is residential, commercial, or is being filled and developed for commercial purposes. North of Highway 183 the creek is small, shallow, and flows only after rains.

PROBLEMS AND NEEDS

The Austin area is experiencing rapid growth in both population and development. Flood damages to human habitations have increased on Shoal Creek because of direct encroachment of developments on the stream. Also, increased storm water runoff, caused by a reduction of soil permeability in the drainage area, has increased flood frequency and magnitude.

Actions to alleviate human suffering and economic losses caused by the high flow periods of Shoal Creek threaten to destroy the natural values of the riparian system. The aesthetic appeal of the creek is created by vegetative diversity. Disruption of the geologic conditions which created the stream, with such structural measures as channelization, could remove forever the last remnants of an irreplaceable resource.

It is evident that the City of Austin recognizes the natural values of Shoal Creek. Seven parks are located on the stream, several associated with greenbelt trail type activities. Between 15th Street and 29th Street, Pease Park and the Shoal Creek Greenbelt have been intensively developed. However, even though Austin has an active Parks and Recreation Department, rapid growth of the city can foreclose options for open space before local government can effect control.

The 1980 Texas Outdoor Recreation Plan (TORP) developed by the Texas Parks and Wildlife Department, provides supply, demand, and projected needs for recreation facilities in both urban and rural areas. Preservation of fish and wildlife habitat along Shoal Creek is compatible with development of greenbelt trail systems for hiking, bicycling, and nature study. Region 12 (Capital Region) of the TORP indicates a 1980 deficit

of 17 miles of urban trails. Metropolitan Austin comprises the bulk of that urban demand in the region. By the year 2000, a demand for 129 miles of trail is anticipated. Land adjacent to Shoal Creek could provide a portion of the area to meet this need.

Results of our field investigation and considerations thus far have made us aware that a Federal flood-control project for Shoal Creek has an excellent opportunity to provide for fish and wildlife conservation in an urban setting. We believe your Planning Division also recognizes this fact, as evidenced by the proposal for nonstructural solutions on a large segment of Shoal Creek. We commend you for this alternative and request that additional consideration be given to extending the nonstructural measures further upstream. Some segments of the creek include important natural areas of high ecological value and adverse impact to these areas could be considered as unacceptable. We need to coordinate very closely to ensure proper consideration of these areas into the project plan. To this end, we realize that more specific data and documentation of existing fish and wildlife resource values need to be developed. We will accomplish this as part of our ongoing effort.

We look forward to continued coordination and cooperation with you and your staff on this project.

Sincerely,

Jerome L. Johnson

Jerome L. Johnson
Field Supervisor

cc:
Regional Director, FWS, Albuquerque, NM (AHR)
Executive Director, TPWD, Austin, TX
Austin Parks and Recreation Department, Austin, TX

Plate 1

LAMAR
BLVD
RD.
MESA DR
360
JUSTIN
BURNET
KOENIG
RIVER
COLORADO
CREEK
51st ST
45th ST
ST
15th
MANOR RD
AIRPORT
SPRINGDALE RD
AUSTIN
WILLIAMSON CREEK

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

June 11, 1984

Colonel Theodore G. Stroup
District Engineer
Corps of Engineers, U.S. Army
P.O. Box 17300
Fort Worth, TX 76102

Dear Colonel Stroup:

This represents planning aid information regarding the proposed Shoal Creek Flood Protection Project located within the City of Austin, Travis County, Texas. The purpose of this planning aid letter is to predict environmental consequences of two action alternatives proposed by your agency to alleviate flooding along Shoal Creek. We will also discuss additional alternatives proposed by the City of Austin. This letter has been coordinated with the Texas Parks and Wildlife Department and does not constitute a report of the Fish and Wildlife Service under Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. et seq.).

EXISTING ENVIRONMENT

As noted in a previous planning aid letter, dated June 15, 1983, Shoal Creek is bordered by residential, commercial, industrial and recreational areas. It is a unique resource that is highly valued by the citizenry of the Austin area.

We continue to believe that Federal involvement can and must seriously consider the importance of Shoal Creek to both human and non-human components of the area. There is an excellent opportunity to provide a project that will alleviate flooding and maintain a high quality environment for urban wildlife.

PROPOSED ALTERNATIVES

City of Austin Alternatives

Pertinent to this discussion is a brief summary of the ongoing measures being planned and implemented along Shoal Creek by the City of Austin. These structural and non-structural measures are designed to alleviate flooding and reduce damage to life and property along Shoal Creek.

EXHIBIT 2

The City's non-structural measures involve two major programs. Austin is in the process of buying and relocating homes and businesses lost or irrepairably damaged by the 1981 flood. The City proposes to continue this program for any subsequent flood damage or losses. Those areas that were bought are being transformed into neighborhood parks or incorporated into the City's network of hike and bike trails. Zoning changes have been instituted to (1) disallow construction in certain flood prone areas that are not presently developed; (2) restrict the kinds and amounts of construction in some portions of the floodplain; and (3) require flood-proof construction in other portions of the floodplain.

Two different structural measures are also being carried out. These include the construction of strategically located multi-purpose detention ponds and the installation of rock gabion blankets. The detention ponds will be located in areas which will serve the public in two ways:

1. during non-flood periods they will serve as athletic fields or play grounds with only soccer goal frames or softball backstops allowed as construction; and

2. during high flow periods, they will impound flood waters and release water slowly into Shoal Creek to alleviate flooding.

The gabion blankets will be used to stabilize stream banks and reduce erosion and siltation. These gabion blankets, where presently installed, are both esthetically pleasing and functional. All areas treated will be incorporated, where feasible, into the City's hike and bike trail system.

City planners predict the combination of non-structural and structural measures implemented and proposed will significantly reduce flooding and flood damage. These measures will also provide for higher quality urban wildlife, since revegetation is also being carried out with native plants. These include both herbaceous and woody components with wildlife and slope stabilization values.

CORPS OF ENGINEERS ALTERNATIVES

Alternative 1 - This alternative includes two structural measures and one non-structural measure. Shoal Creek from north of Highway 183 south to 38th Street is proposed for stabilization as an unlined channel utilizing the natural rock strata. The segment of Shoal Creek from 38th Street south to 15th Street is scheduled for minor clearing and debris removal. The segment from 15th Street south to its confluence with Town Lake (the Colorado River) is proposed to be stabilized by concrete vertical walls and some alignment revision.

Alternative 1 could result in the greatest impacts to urban wildlife in that vegetation would be removed from the upper stream segment to reach an area of stable bedrock and in the lower segment to install a concrete channel. Channel realignment and transition into Town Lake would also disrupt existing vegetation and be detrimental to urban wildlife.

Alternative 2 - This alternative includes one or more underground flood tunnels constructed singly or in tandem to divert only flood flows from Shoal Creek and/or a tributary of Shoal Creek that confluences about 45th Street.

One proposed tunnel would begin at Northwest Park and continue in a southwesterly direction to an outfall into Lake Austin in the vicinity of Mount Bonnell Shores.

A second tunnel would begin in the vicinity of Koenig Lane and Woodrow Avenue and continue in a southwesterly direction to the vicinity of 45th Street. It would then intercept a third channel in that area, and continue in a southwesterly direction to another outfall in the vicinity of Scenic Drive.

These tunnels would be designed to carry only flood flows. Normal flows would remain in the existing channel of Shoal Creek and its tributary. The impacts associated with either or all of these channels are varied. One major impact centers around construction at the point of interception along Shoal Creek and the tributary of Shoal Creek. Inadequate construction safeguards could result in contamination of the creek from erosion and siltation. Another concern is for the disposal of approximately 2-3 million cubic yards of limestone slurry from the tunnel boring. A suitable upland disposal area must be located if this alternative is to be implemented.

No Federal Action - This alternative would result in no Federal involvement. No Federal work would be done to Shoal Creek and any flood reduction would result only from City or private action. The actions proposed or being implemented have been discussed earlier.

FISH AND WILDLIFE RESOURCES

Although fish and wildlife resources in the project area have not been inventoried, general guidance can be provided regarding the possible impacts associated with each alternative. Each alternative discussed earlier in this planning aid letter includes a general description of associated fish and wildlife concerns. More specific analyses and predictions are possible only when a specified plan is adopted. However, we

can predict with a relative degree of certainty those alternatives likely to result in significant adverse impacts to fish and wildlife resources.

The potentially most damaging measures are the channel stabilization of the unlined channel with natural rock strata and concrete vertical walls, along with channel realignment discussed under Corps of Engineers Alternative 1. This would result in the most disruption to the existing ecosystem.

The next potentially damaging measure includes bank stabilization by gabion blankets, if channel sloping and vegetation removal is carried out. This would result in disruptions to the existing ecosystem in those areas that were physically worked. These disruptions would be shorter in duration than the above discussed alternative.

Based upon the information available to us at present, the least environmentally damaging alternative appears to be the underground flood tunnels. This would result in little or no surface disturbance. The only direct impacts would appear to be in the vicinity of the flood interceptor gates and outfall structures. The major concern, as indicated earlier, would be the disposal of the surplus material removed from the tunnel. A suitable disposal site must be located. Possible sources include road construction sites, upland building sites, the limestone quarry near the City of Round Rock, or even private lake owners in East Texas whose waters are too acidic. We urge the Corps of Engineers to carefully consider disposing of this material in an environmentally satisfactory manner.

SUMMARY

Several alternatives have been discussed that will accomplish some level of flood reduction along Shoal Creek in Austin, Texas. The City of Austin is currently carrying out programs to meet that goal. These include floodplain zoning, floodproofing requirements and creek bank stabilization. The Corps of Engineers is currently studying several alternatives that include channel stabilization, concrete wall construction, debris removal, and tunneling.

Potentially, the most environmentally damaging alternative is Corps of Engineers Alternative 1, which includes concrete lining and stream realignment as well as debris removal and channel stabilization with natural rock strata. The least environmentally damaging alternative appears to be the Corps of Engineers tunneling alternative, so long as the material removed from the tunnels is disposed of properly. As soon

as specific project plans are formulated, this office will determine the need for additional studies and will carry them out as appropriate.

Thank you for the opportunity to provide this planning aid. If you have any questions, please contact us.

Sincerely yours,

Jerome L. Johnson

Jerome L. Johnson
Field Supervisor

cc: Regional Director, FWS, Albuquerque, NM (AHR)
Executive Director, TPWD, Austin, TX

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

October 1, 1985

Colonel A.J. Genetti, Jr.
District Engineer
Corps of Engineers, U.S. Army
P.O. Box 17300
Fort Worth, TX 76102

Dear Colonel Genetti:

This represents planning aid information regarding the proposed Shoal Creek Flood Protection project in Austin, Texas. On August 14, 1985, Mike McCollum, of my staff, and Bob Spain of Texas Parks and Wildlife Department visited the project area to evaluate an array of structural alternatives provided by your staff.

PROPOSED ALTERNATIVES

Alternatives evaluated include six (6) plans and are described as follows:

1. Full-length Minimum Channel - This full-length channelization feature would include channel segments varying from 20-90 foot bottomwidth with vertical concrete walls and 1 on 3 feet grassed slopes with topwidths varying from 35 to 188 feet. A 25-foot construction lane on each side of the channel will be provided and add to the topwidth limits. The channel feature would extend from MOPAC Railroad upstream of Highway 183 to Colorado River (Town Lake).

2. Full-length Intermediate Channel - This full-length channel alternative differs from the Full-length Minimum Channel alternative only in channel segment widths. The channel segments would vary from 35-90 foot bottomwidth with vertical concrete walls and 1 on 3 feet grassed slopes with topwidths varying from 60 to 200 feet. Construction lanes will add to the topwidth limits.

3. Full-length Maximum Channel - This channel alternative would include channel segments that vary from 45 - 90 foot bottomwidths with vertical concrete walls and 1 on 3 feet grassed slopes with topwidths varying from 45 - 200 feet. Construction lanes will add to the topwidth limits.

EXHIBIT 3

4. Ten-Foot Combination Plan - This alternative includes limited channel work along with two (2) ten-foot diameter tunnels that carry flood flows from Hancock Creek (at one location) and Northwest Park (a second location) to two outfall locations at Lake Austin. Intermediate channel improvements are proposed which will vary from 30 - 90 foot bottomwidths with vertical concrete walls and grassed slopes with 35 - 120 foot top-widths. Construction lanes (25 feet each side) will add to the topwidth.

5. Eighteen and One-Half Foot Combination Plan - This alternative differs from Alternative Number 4 only in the size of the flood tunnels. They will increase to 18.5 feet in diameter.

6. Twenty Three Foot Combination Plan - This alternative differs from alternatives 4 and 5 only in the size of the flood tunnels. They will increase to 23 feet in diameter.

ALTERNATIVES EVALUATION

Assumptions

The Fish and Wildlife Service's Habitat Evaluation Procedures (HEP) were used to compare impacts of each of the six alternatives discussed. The following assumptions were used in the analysis.

Future Without-A-Project

1. No changes are assumed in without-a-project conditions throughout the project life.

Future With-A-Project

2. The minimum channel project would result in the loss of 174 acres of riparian habitat. There will be 21 acres of riparian habitat remaining with a 90 percent reduction in value.

3. The intermediate channel would result in the loss of 176 acres of riparian habitat. The 19 acres remaining will be reduced in value by 90 percent.

4. The maximum channel would remove all riparian habitat.

5. The combination plans include the 10, 18.5, and 23 foot diameter tunnels. This project would result in the loss of 37 acres of riparian habitat. The remaining 158 acres would retain its baseline value.

6. Since high quality riparian habitat is subject to the greatest degradation, and since grasslands are limited in the project area but <u>not</u> elsewhere in Travis County, our analysis was limited to the riparian habitat.

TERRESTRIAL RESOURCES

Results

Based on the above assumptions, the full-length channel alternatives, regardless of the width, would result in significant losses to fish and wildlife resources. Losses vary from 97 percent for the minimum channel to 98 percent of for the maximum channel. This is due to the fact that the high quality riparian corridor averages only about 100 feet in width with a minimum width of 50 feet and a maximum width of 170 feet.

Table 1 displays the net change in habitat quality for the selected evaluation species for all project alternatives.

Table 1
Net Change in Average Annual Habitat Units

Species	Minimum Channel	Maximum Channel	Intermediate Channel	Combination Plans
Belted Kingfisher	-20	-20	-20	0
Raccoon	-138	-139	-138	-26
Woodrat	-191	-194	-192	-37
Fox squirrel	-145	-147	-146	-28
Green heron	-188	-190	-188	-36
American kestrel	-134	-136	-134	-26
Barred owl	-155	-157	-155	-30
Carolina chickadee	-155	-157	-155	-30
Totals	-1126	-1140	-1128	-213

Based on the data from Table 1, the combination plan, regardless of the tunnel diameter, is the least degrading on fish and wildlife resources and would be easiest to compensate. Mitigation could be in the form of project modifications, including reducing the scope of the clearing along the channel slopes by installing gabion blankets and stair-stepping the slope to protect the riparian vegetation.

Aquatic Resources

The loss of instream flows oftentimes accompanies a local flood control project such as this. Present plans call for the placement of a 36-inch pipe at the diversion sites at Northwest Park and at 45th Street. We believe the reduction of flows with this size pipe will decrease the flushing action significantly and reduce the value of Shoal Creek as a fishery. It is presently supporting a diverse and productive fishery. Numerous spawning beds were observed during the spring.

The existing flushing action associated with above-normal flows maintains the quality of the stream by transferring nutrients throughout the system and keeping the bottom relatively clean.

Because of the need for flushing action, we recommend the project allow the passage of the one-year frequency event. If this causes additional damages to occur with the project in place, please consider increasing the size of the pipe to 42 - 48 inches. Although flows through this size pipe would not be optimum, impacts would be lessened.

Thank you for the opportunity to provide planning assistance. Please contact Mike McCollum at 334-2961 if you have any questions.

Sincerely,

Thomas J. Cloud, Jr.

for Jerome L. Johnson
Field Supervisor

cc: Regional Director, FWS, Albuquerque, NM (AHR)
Executive Director, TPWD, Austin, TX

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

April 14, 1987

Colonel A.J. Genetti, Jr.
District Engineer
Corps of Engineers, U.S. Army
P.O. Box 17300
Fort Worth, Texas 76102

Dear Colonel Genetti:

This is the report of the Fish and Wildlife Service for the proposed Shoal Creek Flood Protection Project located within the City of Austin, Travis County, Texas, prepared under authority of Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It is intended to accompany your report to Southwest Division of the Corps of Engineers and to be included in your environmental assessment.

The City of Austin has suffered from frequent floods resulting from Shoal Creek draining a large area of impermeable surfaces. In 1981, at the request of the Mayor of Austin, a study was undertaken by the Corps of Engineers (CE) to determine the need for Federal participation in a project to alleviate these flooding conditions. This was carried out under the continuing authority of Section 205 of the Flood Control Act of 1948, as amended.

The Service has been involved in project planning since August 1981. We have provided input through the issuance of planning aid letters and participated in scheduled planning team meetings, field trips and informal communication. The results of those activities form the basis for this report. This report has been coordinated with the Texas Parks and Wildlife Department (TPWD).

DESCRIPTION OF PROJECT AREA

Shoal Creek, a tributary of the Colorado River, is located in the west central part of the City of Austin, Texas (Plate 1). The creek traverses this portion of the city from just north of U.S. Highway 183 south to Town Lake (Colorado River). The creek is variously bordered by industry, residences, commercial property and parklands.

The project area cuts through limestone hills that provide rapid storm water runoff with high flows. The upper reach of Shoal Creek that extends from the MOPAC Railroad to near Northwest Park is essentially an ephemeral stream that flows only following localized rainfall. The remainder of Shoal Creek is characterized as intermittent with occasional permanent pools. The upper reaches of Shoal Creek and an affected segment of Hancock

EXHIBIT 4
17 APR 1987

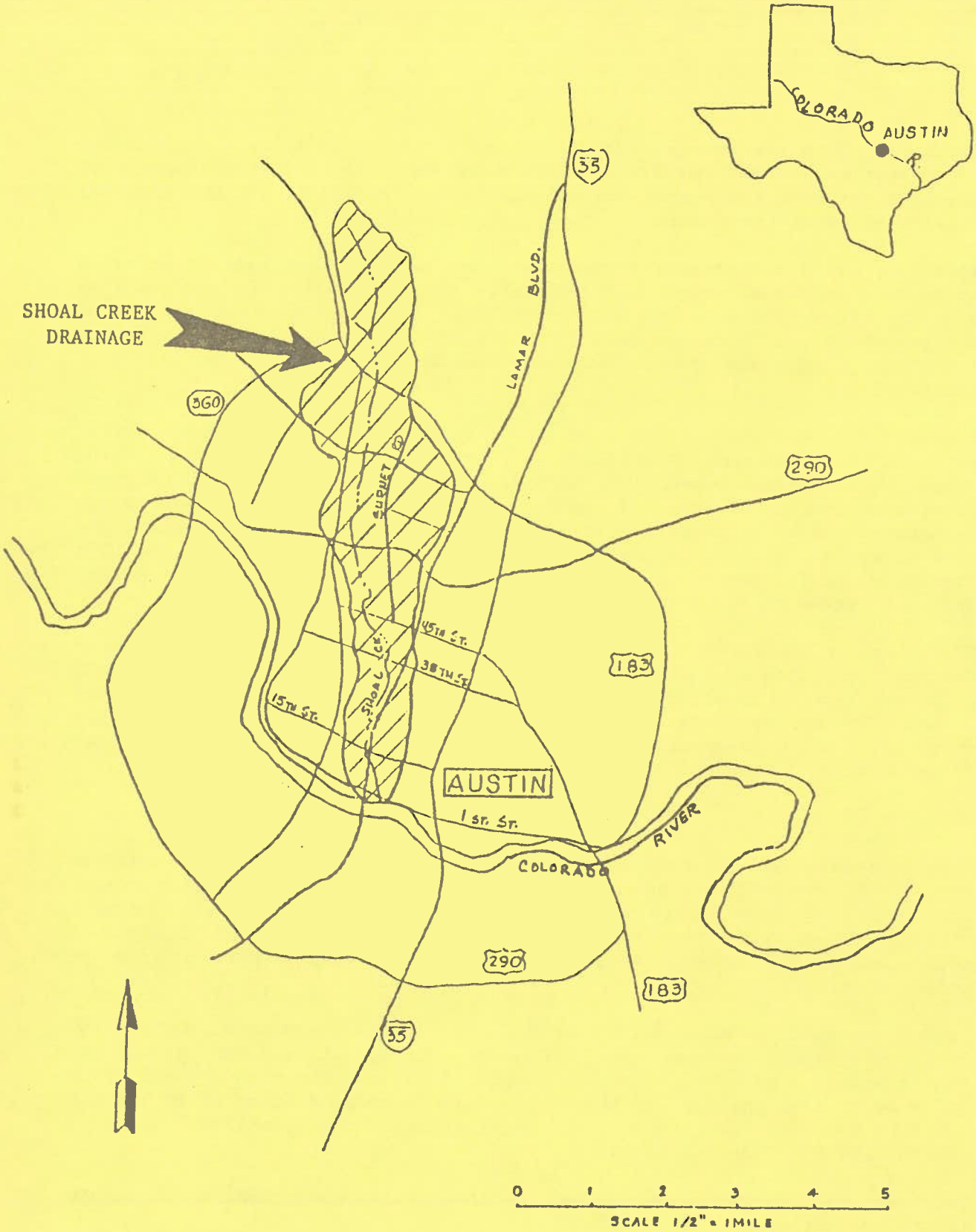


Plate 1
Shoal Creek Drainage Area

Creek have been previously channelized and are maintained as a trapezoidal cross-section. These two areas are bordered by light industry, commercial property and some residences and are adversely affected by the quantity and quality of urban storm water.

Retaining walls consisting of concrete, rock or wood have been constructed to protect adjacent property. The walls occur primarily in the downtown section. Rock gabion stabilization has been installed along a portion of the greenbelt parklands by the City of Austin. Additionally, the city has installed a concrete U-wall and sub-impoundments adjacent to, and in, Northwest Park.

Stream banks are mostly alluvial soils with occasional limestone cliffs bordered by riparian vegetation. The riparian zone is a thin, discontinuous strip immediately adjacent to the stream. Woody vegetation consists primarily of live oak, elm, hackberry, mulberry and juniper, while herbaceous cover is primarily manicured grasses along the residential and park areas. Johnson grass and bermudagrass are abundant along the commercial and industrial segments, particularly where concrete parking does not extend to the top of the cutbank.

The City of Austin is vitally concerned about greenspace. This is evidenced by the existence of almost 120 acres of parks and undeveloped areas adjacent to Shoal Creek. These protected areas provide for a variety of wildlife not found in most urban areas. Shoal Creek and the greenbelt areas provide for compatible coexistence between the human environment and urban wildlife habitat.

PLAN OF DEVELOPMENT

Flash flooding has occurred on Shoal Creek and its tributaries through the years. The high flows that result from periodic intense storms increase the hazard to human life and cause serious damage to the environment through erosion. The resultant deposition of debris and other transported materials at bridge crossings increases the intensity and duration of overbanking.

Nonstructural or passive solutions are not generally practical in heavily urbanized areas because of extensive floodproofing and evacuation requirements. The selected plan attempts to balance the benefits and costs in terms of real dollars and the unquantifiable consideration of intangible benefits to the environment of such natural conditions as periodic overbanking and flushing flows.

Four basic structural measures were considered for preventing flood damage to the project area. These include:

1. Detention ponds,

2. Channel capacity increases by channelization,

3. Levees, and

4. Tunnels.

The City of Austin has recently undertaken certain measures, on their own, to alleviate the flooding. These include the construction of a detention pool in Northwest Park and an in-channel concrete U-wall to funnel water into the pond. Therefore, the Corps of Engineers plan does not include additional detention ponds as a means of storing high flows to be slowly released over time.

The CE selected plan consists of what is referred to as the 18.5-foot combination plan. This plan includes the following features:

1. An increased channel capacity to include a 50-foot bottom width trapezoidal channel extending 1,500 feet from under the MOPAC Railroad to U.S. Highway 183;

2. Two 11-foot conduits under U.S. Highway 183;

3. A trapezoidal grass-lined channel with 35 to 50-foot bottom widths extending 10,500 feet from U.S. Highway 183 through a highly developed commercial and residential area downstream to Northwest Park;

4. An 18.5-foot diameter tunnel diversion (Northwest Park Tunnel) that extends 11,000 feet and empties into Day Creek and then Lake Austin;

5. A 30-foot bottom width, grass-lined, trapezoidal channel on Hancock Creek from just upstream of Burnett Road extending 700 feet upstream to a drop structure and stilling basin;

6. An 18.5-foot diameter tunnel diversion (Hancock Creek Tunnel) beginning at the end of the Hancock Creek channel and extending 4,700 feet to 45th street;

7. An 18.5-foot diameter tunnel (45th Street Tunnel) connecting with the Hancock Tunnel that extends 6,800 feet to an outlet into Lake Austin near Mayfield Park;

8. Stilling basins to be constructed at the two tunnel outlets to reduce diversion water velocity; and

9. The installation of a 42-inch diameter conduit at the Northwest Park Tunnel to allow the passage of normal flows and some higher-than-normal flows that will not be diverted into the tunnel.

In addition to the selected plan, three channelization only plans were also considered. They include:

1. Full-length Minimum Channel - This alternative would include channel segments varying from 20-90 foot bottom width with a

combination of vertical concrete walls and 1 on 3 foot grassed slopes with top width varying from 35-188 feet. A 25-foot wide construction lane on each side of the channel would increase the impact zone. The channel feature would extend from MOPAC Railroad upstream of U.S. Highway 183 to its confluence with the Colorado River at Town Lake. This alternative is referred to as the Minimum Channel.

2. Full-length Intermediate Channel - This alternative differs from the Minimum Channel alternative only in channel segment widths. The channels would vary from 35-90 foot bottom widths with a combination of vertical concrete walls and 1 on 3 foot grassed slopes with topwidths varying from 60-200 feet. Construction lanes would add to the top width. This alternative is referred to as the Intermediate Channel.

3. Full-length Maximum Channel - This alternative differs from the Minimum and Intermediate Channels only in channel segment widths. The channels would vary from 45-90 foot bottom widths with a combination of vertical concrete walls and 1 on 3 feet grassed slopes with top widths varying from 45-200 feet. Construction lanes would add to the top width. This alterntative is referred to as the Maximum Channel.

EVALUATION METHODOLOGY

Terrestrial Resources

Terrestrial evaluations were conducted along Shoal Creek from its headwaters at the MOPAC bridge upstream of U.S. Highway 183 to its confluence with the Colorado River at Town Lake using the Service's Habitat Evaluation Procedures (HEP). HEP is a method which permits the documentation of the quality and quantity of available habitat for selected wildlife species at different time intervals and under varying development levels. HEP is used to quantify and compare habitat in a study area for future without and with project conditions. Habitat quality for selected wildlife species is described by a Habitat Suitability Index (HSI), which is obtained by comparing field measured life requisite variables to optimum criteria for that species. This index value, which ranges of 0 to 1.0 on a ratio scale, is multiplied by the area of available habitat to obtain Habitat Units (HU's). The HU's are used for the alternative future comparisons.

Available habitats were mapped by cover types from existing false-color infra-red photography obtained from the Service's National Wetland Inventory program.

Evaluation species were selected, by a study team comprised of FWS and TPWD personnel, based on the availability of quality models for species that receive life support from the habitats which exist in the Shoal Creek area. They are displayed in Appendix A. Baseline data were obtained by the study team from ten sample sites in the riparian corridor. The evaluation was limited to the riparian corridor because channel modification and habitat alteration were limited to this habitat type.

Analysis of the HEP field data involved the determination of average annual habitat units (AAHU's) for a 50-year period of analysis. This analysis compared the AAHU's for without and with the preferred alternative as well as for all alternatives. This comparison of AAHU's indicates the magnitude of impacts and forms the basis for identifying compensation requirements. The Service has developed a set of guidelines, the Mitigation Policy (Federal Register, Vol. 46, No. 15, Jan. 23, 1981), to assist us in making consistent compensation recommendations commensurate with the quality, scarcity and vulnerability of affected fish and wildlife habitats. The guidelines direct Service personnel to classify habitats into Resource Categories. The Resource Category determination for Shoal Creek identified the riparian corridor for the portion of Shoal Creek from near Northwest Park to its confluence with the Colroado River at Town Lake as a Resource Category II. The remaining upper segment of Shoal Creek, and the affected portion of Hancock Creek, have been designated as Resource Category IV. The rationale for these determinations are contained in Appendix A.

In order to accurately compare the various project alternatives, the study team developed a set of analysis criteria to predict future conditions for without and with project actions. These criteria are also displayed in Appendix A.

Aquatic Resources

The Shoal Creek project area was segregated into three segments for the purposes of our analysis. These segments include the upper reach of Shoal Creek extending from MOPAC Railroad to near Northwest Park; the affected portion of Hancock Creek; and the remainder of Shoal Creek from near Northwest Park to its confluence with the Colorado River at Town Lake. Because the selected plan involves the channelization of previously impacted ephemeral streams, an aquatic analysis was not conducted on the upper portion of Shoal Creek or the affected segment of Hancock Creek. An aquatic analysis was also not conducted on the remaining portion of Shoal Creek, since the tunnel and conduit phase of the project is not anticipated to impact that stream segment.

FISH AND WILDLIFE RESOURCES WITHOUT THE PROJECT

Terrestrial Resources

Shoal Creek serves as an oasis for urban wildlife in the Austin area. It is a unique blend of residential and natural areas that interface with a limestone stream. The City of Austin has taken pride in this valuable resource as evidenced by the many parks and greenbelts that line the stream.

A survey identified 25 species of trees, 15 species of shrubs and vines, and 70 herbaceous species in the project area. Checklists of terrestrial species known to occur in the project area include 64 species of birds, 28 species of reptiles and amphibians, and 25 species of mammals. Most notable examples include such avian species as green heron, American kestrel, sandpiper, mourning dove, owls, belted kingfisher, and grackle. Amphibian and reptiles of note include frogs, toads, softshell, redear and snapping turtles, and water snakes. Noteworthy mammals include bats,

opossum, cottontail rabbit, small rodents, ringtail and raccoon. The diversity of species in the project area emphasizes the importance of the riparian corridor of the lower segment of Shoal Creek and justifies its designation as a Category II Resource.

As indicated in our HEP analysis criteria (See Appendix A), we anticipate no measurable change in quantity or quality of riparian habitat along Shoal Creek in the future without a project. Table 1 displays the results of our HEP analysis for future conditions without a project.

Table 1
HEP Analysis - Preferred Plan
Without a Project - Future Conditions

Evaluation Elements	Acreage	HSI	AAHU's
Belted kingfisher	42	.78	33
Raccoon	195	.72	140
Eastern woodrat	195	1.00	195
Fox squirrel	195	.76	148
Green heron	195	.98	191
American kestrel	195	.70	137
Barred owl	195	.81	158
Carolina chickadee	195	.81	158
TOTALS	1,407		1,160

Because we have assumed no measurable change in quality or quantity of habitat throughout the period of analysis and the current HSI values are relatively high, the lower segment of Shoal Creek is predicted to maintain a high quality terrestrial environment in the future with no project.

Aquatic Resources

Although no formal analysis of aquatic resources was carried out, we are not discounting the quality of the lower segment of Shoal Creek. Approximately 30 species of fish have been identified. Recruitment occurs from Town Lake, an impoundment on the Colorado River. Notable fish species include shad, carp, and catfish, as well as bluegill, largemouth bass and other sunfish. This stream segment, though intermittent, is characterized by deep holes and other permanent water located upstream of dams and other constrictions in the stream. Valuable riffle-run segments increase the streams value to terrestrial species as does the shading provided by adjacent and overhanging vegetation. The existing value is anticipated to remain unchanged without a project.

FISH AND WILDLIFE RESOURCES WITH A PROJECT

Terrestrial Resources

Our impact analysis compared changes in quantity and quality of habitat associated with the preferred alternative as well as the three channelization alternatives (Table 2).

Table 2
Net Change in AAHU's - HEP Analysis
With a Project

Evaluation Element	Preferred Alternative	Minimum Channel	Intermediate Channel	Maximum Channel
Belted kingfisher	0	-20	-20	-33
Raccoon	-26	-138	-138	-140
Eastern woodrat	-37	-191	-194	-195
Fox squirrel	-28	-145	-146	-148
Green heron	-36	-188	-188	-191
American kestrel	-26	-134	-134	-137
Barred owl	-30	-155	-155	-158
Carolina chickadee	-30	-155	-155	-158
TOTAL	-213	-1126	-1130	-1160

Impacts to the riparian habitat of Shoal Creek would result from channel widening to increase capacity. Significant impacts would be limited to the lower segment of Shoal Creek from near Northwest Park to the confluence with the Colorado River at Town Lake. Channelization in that segment would destroy the riparian corridor and virtually eliminate the terrestrial wildlife species associated with that segment of Shoal Creek. The three channel widening alternatives would result in loss of 94-100 percent of the habitat (Table 3). Conversely, the preferred alternative would concentrate the impacts to the lower quality and previously channelized upper segment of Shoal Creek and the affected portion of Hancock Creek. Therefore, only Resource Category IV areas would be impacted. Losses with this alternative are projected to be 17 percent (Table 3).

Table 3
Percent Change in AAHU's (Loss)
Without vs With a Project

Evaluation Element	Preferred Alternative	Minimum Channel	Intermediate Channel	Maximum Channel
Belted kingfisher	0%	61%	61%	100%
Raccoon	19%	99%	99%	100%
Eastern woodrat	19%	98%	98%	100%
Fox squirrel	19%	98%	99%	100%
Green heron	19%	98%	98%	100%
American kestrel	19%	98%	98%	100%
Barred owl	19%	98%	98%	100%
Carolina chickadee	19%	98%	98%	100%
AVG.	17%	94%	94%	100%

Aquatic Resources

With exception of the trapezoidal, previously altered stream segments mentioned above, the remainder of the Shoal Creek stream zone will suffer little or no modification with the preferred alternative. One modification is the intake structure at each tunnel entrance. The intake structure has been designed to pass normal flows, via 42-inch conduits, and to maintain, as nearly as possible, annual storm events that contribute periodic flushing flows.

Conversely, either of the three full length channel alternatives would eliminate the aquatic environment as it presently exists. Total loss of aquatic resources would result.

DISCUSSION AND RECOMMENDATION

The Service recommends the development of the preferred alternative identified as the 18.5-foot Tunnel Project. Because this alternative incorporates design features which avoid or significantly reduce impacts to fish and wildlife resources, no additional mitigation is deemed necessary.

It has been a pleasure to work with such a receptive planning team. We look forward to this type of relationship on all future projects.

Sincerely,

Jerome L. Johnson

Jerome L. Johnson
Field Supervisor

cc: Regional Director, FWS, Albuquerque, NM (AWE)
Executive Director, TWPD, Austin, TX
Branch of Federal Projects, Washington, D.C.

IN REPLY REFER TO:
2-12-89-I-392

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

September 25, 1989

Mr. Michael J. Mocek, P.E.
Chief, Planning Division
Department of the Army
Fort Worth District
Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

Dear Mr. Mocek:

This responds to your letter of September 11, 1989, regarding the Shoal Creek flood protection project for Austin, Travis County, Texas. Your letter itemized amendments to the project previously described in our April 14, 1987, Fish and Wildlife Coordination Act report.

The amendments include relocating tunnel intake and outlet structures and the addition of a tunnel at Hancock - 45th Street. A potential alternative to the Hancock - 45th Street tunnel is a combination concrete u-wall channel with a box culvert and a grass-lined channel. Mike McCollum, of my staff, has previously accompanied Ms. Janis Cullum and Mr. Bob Shelton of your staff on a trip to investigate these amendments. As a result of that trip and following discussions with your staff, we concur with the amendments and believe either their implementation or implementation of the alternative to the Hancock - 45th Street tunnel will not result in significant impacts to fish and wildlife resources.

Your September 11, 1989, letter also specifically requested comments regarding endangered or threatened species. Six species are listed as endangered for Travis County. These include:

(1) Black-capped vireo - Vireo atricapillus
(2) Bee Creek cave harvestman - Texella reddelli
(3) Kretschmar cave mold beetle - Texamaurops reddelli
(4) Tooth cave pseudoscorpion - Microcreagris texana
(5) Tooth cave ground beetle - Rhadine persephone
(6) Tooth cave spider - Leptoneta myopica

A review of our records indicates that none of the six species are documented as occurring in the project area. Therefore, we do not anticipate that the amended project will have an impact on endangered or threatened species.

EXHIBIT 5

Since the amended project will result in fewer impacts to fish and wildlife resources in the project area than anticipated with the original project, we concur with the amendments as proposed.

Thank you for the opportunity to provide comments. If you have any questions, please contact Mike McCollum at 817-334-2961.

Sincerely,

Robert M. Short

Robert M. Short
Field Supervisor

cc: Regional Director, FWS, Albuquerque, NM (AWE-HC)
Executive Director, TPWD, Austin, TX (Resource Protection Division)

EVALUATION OF THE DISCHARGE
OF DREDGED AND FILL MATERIAL IN ACCORDANCE
WITH SECTION 404(b)(1) GUIDELINES
40 CFR 230

I. PROJECT DESCRIPTION

The proposed plan for flood control improvements along Shoal Creek in Austin, Texas, includes a 1.8-mile channel improvement in the upstream reach, a short channel improvement on Hancock Creek (a tributary of Shoal Creek) and two tunnel systems diverting excess storm flow to Lake Austin and Town Lake. Each tunnel system consists of intake and diversion structures on Shoal Creek, 14.0-foot diameter tunnel, and an tunnel outlet with a short channel reaching one of the two lakes. Authority for the proposed action is contained in the Flood Control Act of 1936, Section 6; Committee on Commerce Resolution of 1936; River and Harbor Act of 1937, Section 4; and River and Harbor Act of 1945, Section 6. Other project details are outlined in the Environmental Assessment.

II. RESTRICTIONS ON DISCHARGES

After completing the technical evaluation, the proposed discharge will be evaluated against the restrictions specified in this section. A statement of compliance or noncompliance will be included in the Environmental Assessment.

SUBPART A - ACCEPTABILITY

Dredged and fill material should not be discharged into the aquatic ecosystem unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact either individually or in combination with other known and/or probable impacts of other activities affecting the ecosystem of concern.

SUBPART B - RESTRICTIONS

1. (a) Will this project involve a discharge into a special aquatic site?

/x/ No (See 2) ☐ Yes (See 1(b))

(b) Does the project require location within such a site to fulfill its basic purpose? Why?

☐ No (See 1(c)) ☐ Yes (See 2)

(c) Considering cost, technology, and logistics, discuss apparent practicable alternatives to the project not involving discharges into a special aquatic site or demonstrate the lack of such alternatives. (Proceed to 3).

2. Considering cost, technology, and logistics, discuss apparent practicable alternatives to the discharge which will achieve the project purpose. Only those alternatives which appear to have less impact on the environment need be discussed.

Practicable alternatives to the proposed action include a no action alternative, three extensive channel plans of various sizes, and three channel-tunnel combination plans of different tunnel dimensions having two outlets on Lake Austin. The no action plan would provide the least impact upon the aquatic and riparian environment; however, to continue to risk life and property is totally unacceptable. Any of the three extensive channel plans will require a greater removal of riparian and aquatic habitat than the proposed action. The three channel-tunnel plans are similar to the proposed action and do not differ significantly in environmental impacts. Other alternatives were investigated and found impracticable. The proposed action has the highest net benefits of all alternatives studied.

3. Will any of the above alternatives have less adverse impact on the aquatic ecosystem or other environmental values than the applicant's proposal? Your answer should reflect a comparison of alternatives made pursuant to Subparts C-F and other environmental documentation necessary to support the answer.

/X/ No */_/ Yes

4. Has the discharge been certified as being in compliance with State Water Quality Standards?

*/_/ No /_/ Yes Date_____

5. Does the project appear to violate applicable Federal toxic effluent standards developed pursuant to Section 307 of the CWA (40 CFR 219)?

/X/ No */_/ Yes

6. Will this project jeopardize the continued existence of critical habitat of species listed as threatened or endangered under the Endangered Species Act of 1973?

/X/ No */_/ Yes

7. Will the project violate any requirement established by the Secretary of Commerce to protect any marine sanctuary?

/X/ No */_/ Yes

8. As determined in Subpart C-G of this evaluation, will this project contribute to significant degradation of waters of the United States including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values?

/X/ No *// Yes

9. Have appropriate and practical steps been identified in Subpart B which would minimize potential adverse impacts of the discharge on the aquatic ecosystem?

/X/ No (Evaluation Complete) **// Yes (See 10(a))

10. (a) Will such steps be incorporated into the project design?

**// No // Yes

(b) or will they be required by permit conditions or other agreements?

**// No // Yes

* An answer annotated by an asterisk indicates that the discharge is not in compliance with 40 CF 230.

**An answer annotated by a double asterisk indicates that the proposed discharge is not in compliance with 40 CFR 230 when marked in three consecutive places.

III. ANALYSIS OF PROJECT IMPACTS ON THE AQUATIC ECOSYSTEM

Subparts C-F of this section should provide technical analysis of project impacts on the aquatic ecosystem. Discuss any appreciable changes to the specified portion of the aquatic ecosystem which would result from the applicant's proposal and any design features of the proposal which would minimize adverse effects. Compare such impacts with those of any practicable alternatives.

SUBPART C - PHYSICAL AND CHEMICAL IMPACTS

Your discussion should include any pertinent information about primary, secondary or cumulative impacts of the work on the substrate (S. 230.20); turbidity/suspended particulates (S. 230.21); physical and chemical changes to the water column (S. 230.22); current, circulation, or fluctuation (S. 230.23-24); and salinity gradients (S. 230.25).

o Deposition of fill material will be confined to relatively small areas of the general project area. Fill material will consist of native soils and rocks, riprap, and concrete. For the channelized portion of Shoal Creek, the placement of native soil and rock fill will be limited to a few areas where unwanted depressions exist and channel realignment requires. Excavated material will be primarily used as the soil and rock fill and is, therefore, chemically and physically similar to the existing

stream substrate. As the fill material is initially compacted, water and gases will be squeezed from void spaces between particles. However, after the re-establishment of rooting plants, the substrate will retain much of the original characteristics. Riprap will be used adjacent to bridges, tunnel inlets, and stilling basins, where erosion tends to occur. Riprap will be composed of similar rock or inert materials and overlay a relatively small portion of the project area. To construct tunnel intake structures, small perforated diversion dams, outfall structures, and stilling basins, concrete will be placed over compacted soils. Concrete construction will permanently displace little aquatic life in relatively small areas in Shoal Creek. After placement, the concrete will prevent the natural exchange of nutrients and gases between substrate and the water interface. During construction activities, care will be used to restrain excavation materials from entering Lake Austin. Extraneous fill material removed from all construction sites will not be deposited in other streams, wetlands, or adjacent inundated areas (S. 230.20).

o After project completion, initial stormwater will purge streambed surfaces and former construction sites of loose sediments and particulates associated with construction. This event will cause a minor temporary increase of turbidity within the water columns of Shoal Creek, Lake Austin and Town Lake near outfalls until suspended materials settle. With subsequent diversions, there would be a slight increase, though relatively infrequent and temporary with each episode, of turbidity near the outfall on Lake Austin. Diversions to Town Lake will carry a portion of the suspended particulate load that is typically carried to Town Lake. Suspended particulates will be added to Lake Austin with diversion water, but the total particulate load will not be significantly increased within the lake (S. 230.21).

o No permanent changes in physical or chemical characteristics of the water column will directly occur due to fill material placement. Temporary changes will occur as diverted stormwaters from Shoal Creek bring additional nutrients to Lake Austin. Diversions to Town Lake will have negligible effects on water quality since Town Lake normally receives flows from Shoal Creek. The nutrient additions to Lake Austin will be relatively infrequent and minor. The diversions should slightly increase algae productions in Lake Austin, but will have insignificant changes in dissolved oxygen, clarity, and pH in Lake Austin. Temporary changes in water clarity will be principally associated with the resuspension of loose sediments and particulates. These changes will not significantly impact downstream and lake aquatic life (S. 230.22).

o The placement of fill material within Shoal Creek, its tributary, and near the outfalls by Town Lake and Lake Austin will not significantly affect current patterns or water circulation. Subsequent diversions of high stormwaters will have a more direct effect than the deposition of fill material itself. However, as result of project diversions, the changes in flow direction will not significantly impact the existing aquatic habitats. Low, normal, and a portion of high stormflows will continue to pass downstream Shoal Creek and subsequently reach Town Lake. In addition, Town Lake will also receive a portion of the diverted flows from Shoal Creek through the lower tunnel. Diverted flows to Lake Austin

through the upper tunnel will also eventually reach Town Lake through releases to maintain constant surface level in Lake Austin. Fill material will not significantly change the streambed elevation to alter the lake surface elevation. Any changes in flow directions should not be significant to affect the existing aquatic life resident in Shoal Creek, Lake Austin, and Town Lake (S. 230.23-24).

o The project area waters do not interface with coastal marine waters; therefore, salinity gradient considerations are not applicable (S. 230.25).

SUBPART D - BIOLOGICAL IMPACTS

Your discussion should include pertinent information about primary, secondary, and cumulative impacts of the work on threatened and endangered species (S. 230.30); aquatic organisms (S. 230.31); and wildlife (S. 230.32).

o Within construction areas of the proposed project, no impacts to species Federally listed as endangered or threatened or proposed to be listed under the Endangered Species Act will occur (S. 230.30).

o Project channelization will be confined to the upstream area of Shoal Creek and a small segment of its tributary, Hancock Creek. Most of the upstream area is intermittent and relatively limited in aquatic habitat. Channelization will destroy or temporarily displace some of the amphibian habitats. However, very few, if any, fish and crustacean habitats will be lost through the channelization. Construction of intake and diversion structures on Shoal Creek and its tributary should likewise affect few aquatic habitats. Furthermore, sufficient flows will pass these structures to maintain downstream aquatic life. On both lakes, relatively small areas of vegetation and habitats will be removed with the construction associated with where the short outfall channels run into the lakes. Fish will be displaced as habitats are removed or temporarily removed for construction purposes. On the lakes, turbidity will be limited to construction areas. Littoral plants in nearby shallow waters may become temporarily covered with construction dust, but no significant long-term effects will occur (S. 230.31).

o Few stands of hardwoods will be removed because of construction activities along Shoal Creek. The upstream portion of Shoal Creek to be channelized is predominately grassland with very few native trees or urban with only a few introduced trees adjacent to the watercourse. Near Lake Austin, very few trees, if any, would be removed near the tunnel outfall site. Relatively few trees will be removed from around the Town Lake tunnel outfall. Ample riparian habitat should remain at construction sites to sustain all of the original wildlife. Excessive tree removal will be avoided at all construction areas (S. 230.32).

SUBPART E - IMPACTS ON SPECIAL AQUATIC SITES

Discuss any change to special aquatic sites (S. 230.40-230.45) resulting from the applicant's proposal. The discussion should include pertinent information about primary, secondary, and cumulative impacts of the work on values associated with each special aquatic area.

No special aquatic sites reside within the project area. Furthermore, no downstream special aquatic sites will be affected by the proposed action.

SUBPART F - IMPACTS ON HUMAN USE CHARACTERISTICS

The discussion should include pertinent information about primary, secondary, and cumulative impacts of the work on municipal and private water supplies (S. 230.50); recreational and commercial fisheries (S. 230.51); water related recreation (S. 230.52); esthetics (S. 230.53); and designated parks and preserves (S. 230.54).

o Lake Austin and Town Lake are both used as water supplies for the city of Austin, Texas. No changes in water quality due to the proposed action will significantly alter the treatment or quality of potable water for either of these lakes (S. 230.50).

o Lake Austin and Town Lake are used for recreational fishing. Fishing in Shoal Creek is not substantial and is limited to the occasional fisherman in the small impoundment on Shoal Creek. As noted earlier, aquatic life in either Lake Austin or Town Lake will not be significantly affected with fill deposition or by flow diversion (S. 230.51).

o Water related recreation will not be significantly affected by project implementation. Outlet structures will not significantly affect boating activities. No designated swim areas are located near proposed outfall sites. Shoal Creek is too shallow and intermittent for such activities (S. 230.52).

o The aesthetic quality of Shoal Creek will essentially remain the same. Scenic areas of the stream will remain unaltered. Channel construction areas of Shoal Creek are primarily located in areas of open grassland or urban encroachment of lower aesthetic value. The tunnel intake and diversion structures are located in park areas but will be designed to be aesthetically acceptable with low structural profile, adjacent tree and shrub plantings, structural coloring, and berming as needed. Near Lake Austin and Town Lake, outfalls may slightly lessen the aesthetic appeal, but will not significantly affect the overall aesthetic appeal of the lake areas (S. 230.53).

o Three city park areas will be affected with construction. The intake and diversion structures are located in Northwest and Pease Parks along Shoal Creek. With the aesthetic measures to be taken (discussed above), there will be no significant effects. In Pease Park, one or two frisbee goals may need to be moved, but there is still sufficient land for

the frisbee course. As a result of the outlet channel passing through Deep Eddy Park near Town Lake, two baseball fields, some concession buildings, and a service road will be moved slightly west of their current location. Foot bridge will be constructed to provide pedestrian access in Deep Eddy Park. Park land taken by construction in Deep Eddy Park will be mitigated through a purchase of additional land for recreation or through the optional construction of a scenic lagoon in the outlet area. All construction sites along the Shoal Creek, its tributary, and Town Lake are not located in areas of known cultural resources. General literature survey shows there to be no known cultural resources at the Lake Austin outfall construction site. An archeological field survey will be conducted here and at the Lake Austin tunnel outlet prior to construction to locate sites. Should any sites be discovered during construction, such findings will be treated under procedures of preservation law (S. 230.54).

SUBPART G - EVALUATION AND TESTING

1. Describe the source and type of dredged or fill material including land use patterns, potential sources of municipal or industrial pollutants and route of such contaminants to extraction site, significant introduction of persistent pesticides, and possible sources of natural materials which might produce harmful effects on the aquatic environment as a result of man induced discharge activities. (For open water disposal projects include a discussion of site characteristics found in 40 CFR 230.11(f)). List sources from which this information was derived including drainage maps, pollutant discharge or spill records, previous testing, personal communication, etc.

Except for limited quantities of concrete and riprap, all soil and rock fill will be taken from excavated project areas. Relatively small amounts of fill material will be discharged in areas where the channel is realigned or straightened. Limited quantities of concrete and riprap will be applied for diversion, tunnel intake, and outfall structures. Excess fill material will be disposed at a remote site that is above the headwaters and above the normal high water marks.

2. Based on the above discussion, is the extraction site sufficiently removed from sources of pollution to provide reasonable assurance that the proposed discharge material is not a carrier of contaminants?

☐ No (See 3) ☒ Yes (Proceed to 6)

3. (a) Is the discharge material composed predominantly of sand, gravel or other naturally occurring inert material?

☐ No (See 4) ☐ Yes (See 3b)

(b) Are there any indications of contamination such as discoloration, odor, prevalence of dead vegetation or other physical appearance?

☐ No (Proceed to 6) ☐ Yes (Proceed to 5)

4. (a) Is the discharge site adjacent to the extraction site and subject to the same sources of contaminants?

/_/ No (See 5) /_/ Yes (See 4b)

(b) Is the material at the two sites substantially similar?

/_/ No (See 5) /_/ Yes (See 4c)

(c) Can the dissolved and suspended particulates be controlled to prevent possible contamination of other areas?

/_/ No (See 7) /_/ Yes How? (See 6)

5. (a) There is a high probability that the high discharge material may be a carrier of contaminants. Are there any constraints available to reduce contamination to acceptable levels within the disposal site and prevent transport of contaminants beyond these boundaries?

/_/ No (See 7) /_/ Yes (See 5b)

(b) Describe available constraints including their acceptability to applicant. Insure that the impacts of discharging this potentially contaminated material are adequately addressed below o in other portions of this document. (See 6).

6. Based on this evaluation there is little likelihood that discharges associated with the applicant's project or any practicable alternatives will result in contamination of the aquatic ecosystem; therefore, no testing will be required.

/_/ No (See 7) /x/ Yes (Proceed to Subpart H)

7. Based on this evaluation there is reason to believe that the applicant's project or its practicable alternatives may result in degradation of water quality; therefore, the following tests were performed to analyze the discharge material and predict its impact on the aquatic ecosystem. Describe tests and results. Make statement as to acceptability of impacts.

IV. SUBPART H - ACTION TO MINIMIZE ADVERSE EFFECT

Identify practicable actions which are not part of the applicant's current proposal but could be taken to minimize significant adverse effects of the proposed discharge. Discussion of the benefits to be derived from each of these actions should be related to effects specified in the appropriate Subpart of this document. Actions to be considered may include those concerning location of the discharge (S. 230.70); material to be discharged (S. 230.71); controlling pollution from discharge area (S. 230.72); method of dispersion (S. 230.73); technological innovations (S. 230.74); actions affecting plant and animal populations (S. 230.75); and those affecting human use of the aquatic ecosystem (S. 230.76).

All practicable methods to minimize adverse effects were considered in the design of the proposed project. Contractors will be required to use best engineering techniques to avoid unnecessary adverse effects.

BARNEY M. DAVIS, SR., SOMERVILLE
CHAIRMAN
MRS. MENTON MURRAY, SR., HARLINGEN
VICE-CHAIRMAN
RICHARD H. COLLINS, DALLAS
SECRETARY
MRS. JAMES F. BIGGART, JR., DALLAS
DUNCAN E. BOECKMAN, DALLAS
MRS. H. R. BRIGHT, DALLAS
CLIFTON CALDWELL, RICHARDSON

KENYON CLAPP, SALADO
MRS. JOHN B. CONNALLY, HOUSTON
MRS. KENNETH DANKLEFS, AUSTIN
WOODROW GLASSCOCK, JR., HONDO
DORSEY B. HARDEMAN, AUSTIN
MRS. ALBERT G. HILL, DALLAS
MRS. H. L. LONG, KILGORE
MRS. ARGYLE A. McALLEN, LINN
LOUIS P. TERRAZAS, SAN ANTONIO
DR. DAN A. WILLIS, FORT WORTH

TEXAS HISTORICAL COMMISSION

P.O. BOX 12276
AUSTIN, TEXAS 78711

TELEPHONE
(512) 475-3092

October 29, 1982

Theodore G. Stroup
Colonel, CE
District Engineer
Department of the Army
Fort Worth District, Corps
of Engineers
P.O. Box 17300
Fort Worth, Texas 76102

Attn: SWFED-PF

Dear Colonel Stroup:

We have reviewed the Notice of Initiation concerning the Feasibility Study for Flood Damage Reduction on Shoal Creek, Austin, Texas. In checking our maps and files, we find there are a number of archeological sites along the creek, such as 41TV137, 55, 53, 54, 298, and 41TV297. We recommend that an historic and prehistoric archeological assessment be accomplished for the project area according to 36 CFR, Part 800. Upon receipt of the archeologist's report we will respond regarding project impacts on sites potentially eligible for the National Register of Historic Places.

Thank you for the opportunity to participate in the review process.

Sincerely,

Patienne E. Patterson for
LaVerne Herrington, Ph.D.
Deputy
State Historic Preservation
Officer

PEP/LH/lft

EA -93

THE STATE OF TEXAS

CURTIS TUNNELL
EXECUTIVE DIRECTOR

TEXAS HISTORICAL COMMISSION

P.O. BOX 12276 AUSTIN, TEXAS 78711 (512) 475-3092

January 14, 1986

Mr. Michael J. Mocek, P.E.
Chief, Planning Division
Department of the Army
Fort Worth District, Corps
of Engineers
Post Office Box 17300
Fort Worth, Texas 76102-0300

Re: Archeological Assessment, Shoal
Creek, Austin, Travis Co., TX
(COE-FWD, C3, I2)

Dear Mr. Mocek:

Thank you for providing our office a copy of the above referenced assessment which is well written and concise. Our maps and site files have been updated with this information. We look forward to future consultation with your office if the project moves forward.

Sincerely,

LaVerne Herrington

LaVerne Herrington, Ph.D.
Deputy
State Historic Preservation
Officer

NK/LH/mes

The State Agency for Historic Preservation

EXHIBIT 8

THE STATE OF TEXAS

CURTIS TUNNELL
EXECUTIVE DIRECTOR

TEXAS HISTORICAL COMMISSION

P.O. BOX 12276 AUSTIN, TEXAS 78711 (512)463-6100

June 16, 1989

Mr. Michael J. Mocek, P.E.
Chief, Planning Division
Department of the Army
Fort Worth District, Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Re: Shoal Creek Project, Reconnaissance of New Tunnel Outlets, Travis County, Texas (COE-FWD, A5)

Dear Sir:

Thank you for the information on the new proposed tunnel outlets for the Shoal Creek flood control project. A check of our files shows that we have no new information on archeological sites within the project area that was not included in your 1985 report. We concur that the investigation of the area below the terminus of West Lynn St. suggesting that no cultural resources eligible for the National Register of Historic Places will be affected. We recommend that construction be allowed to proceed in that area. Should any possibly significant cultural resources be uncovered during construction, work should cease in that immediate area and our office should be contacted.

We also agree that the Bull Creek tunnel outlet area should be surveyed when access is available. If project plans change or if several years pass before the project is finalized, we recommend that you check with us again for updates on any new data that may become available.

If we may be of further assistance, please contact Dan Prikryl of my staff at (512) 463-6096.

Sincerely,

James E. Bruseth, Ph.D.
Deputy State Historic Preservation Officer

DP/JEB/jkm

DATE

Planning Division

LOCAL FLOOD PROTECTION PROJECT
SHOAL CREEK
AUSTIN, TEXAS

PUBLIC NOTICE

Interested parties are hereby notified that the District Engineer, Fort Worth District, proposes flood control improvements along Shoal Creek in Austin, Texas.

Statutory Authority. This public notice is being issued to all interested parties in accordance with the provisions of Public Law 91-190, The National Environmental Policy Act of 1969. Authority for the proposed action is contained in the Flood Control Act of 1936, Section 6; Committee on Commerce Resolution of 1936; River and Harbor Act of 1937, Section 4; and River and Harbor Act of 1945, Section 6.

History and Purpose. By letter dated July 1981, the Mayor of Austin requested that the Fort Worth District, U.S. Army Corps of Engineers, investigate flooding problems along Shoal Creek and to recommend potential solutions. Under authority of Section 205 of the Flood Control Act of 1948, a reconnaissance study was made which showed that enough damageable property existed in the flood plain to warrant more detailed studies to determine the Federal interest for construction of a flood control project. Results of the reconnaissance study were forwarded to higher Corps offices for review and, subsequently, a detailed project study was initiated under the specific authorization for Colorado River and Tributaries under the Flood Control Act of 1936 and subsequent acts. This public notice presents the results of detailed studies and provides the recommendations of the Fort Worth District for public review and comment.

Proposed Action. Initially, several basic structural and nonstructural measures were studied. Structural measures included detention reservoirs, channel improvements, levees, and tunnels. Basic nonstructural measures included flood proofing, zoning, permanent evacuation, and flood warning. After the initial analysis, seven alternatives were investigated in detail. The seven alternatives included a 'no action' plan, three channel plans, and three channel-tunnel combination plans. The "no action" alternative simply pertains to the probable future condition of the study area in the absence of a structural or nonstructural plan to reduce damages.

EXHIBIT 10

Channels in combination with tunnels were found to be more feasible than comprehensive channel plans. A total of six combination plans were investigated.

In a previous public notice dated June 23, 1987, and at a public meeting held on August 12, 1987, the Corps recommended a preliminary channel-tunnel combination plan that had two outfalls on Lake Austin, but was later revised because of public concern over potential impact of the outfall location on water quality, lakeside residences, and aesthetic and cultural points of interest. The revised plan consists of two smaller tunnels having different locations: one tunnel on Lake Austin away from areas of concern and one on Town Lake.

The Recommended Plan for flood damage reduction basically consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek; a 40- to 50-foot bottom width, concrete-lined channel in Hancock Creek (Shoal Creek tributary); and two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends approximately 400 feet downstream of Foster Lane. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall on Lake Austin near Bull Creek. The lower tunnel system consists of an intake on Shoal Creek in Pease Park near 19th Street, an outfall just east of Pressler Avenue with stilling basin in a small ditch-like tributary just south of the Missouri Pacific Railroad tracks southwest of Orchard Road, and a 60-foot bottom width, grass-lined channel linking the stilling basin with Town Lake. All tunnel intakes are accompanied with diversion structures, and both outfalls are accompanied with stilling basins. The Northwest Park diversion will allow the passage of flows of 1,000 cubic feet per second downstream. The 19th Street Tunnel diversion structure will allow low flows to pass by a 42-inch culvert through the diversion dam. In addition, improvements on Hancock Creek include a concrete U-wall channel from Houston Street to Burnet Road; an attached box culvert under a shopping center; and a concrete channel continuing from the box culvert above Hancock Drive, transitioning to a grass-lined channel, and ending about 700 feet downstream of the drive.

The Recommended Plan also includes a linear recreation plan. The recreation plan includes a 1.4-mile trail for hiking, biking, and nature study, and park benches. Recreation average annual benefits are $77,000, and annual charges are $30,000 which includes $10,000 for operation, maintenance, and replacement. The recreational benefit-to-cost ratio is 2.6 to 1.0. The annual charges and annual benefits of the recreation are included in the cost for the Recommended Plan.

The Recommended Plan has a first cost of $82,272,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of $39,000 annually; and average annual benefits of

$11,974,000. The Recommended Plan is the NED plan. The attached project map depicts the Recommended Plan.

The environmental aspects of this project and its alternatives were considered in a preliminary Environmental Assessment prepared by the Fort Worth District. A preliminary Finding of No Significant Impact has been made which, pending receipt of public comments to the contrary, will be finalized at the end of the comment period. A preliminary Section 404(b)(1) evaluation has been completed and is attached as an exhibit to the preliminary Environmental Assessment. Another public meeting will be scheduled in the near future. Copies of the Environmental Assessment are available from the Fort Worth District, Planning Division, ATTN: CESWF-PL-R, P.O. Box 17300, Fort Worth, Texas 76102-0300, upon request.

Any comments on the proposed action should be received no later than 30 days from the date of this notice. If no comments significantly affecting the decision are received by that date, it will be considered that there are no overriding objections. For further information, contact Mr. Bob Shelton, Planning Division, Fort Worth District, at (817) 334-2095.

William D. Brown
Colonel, Corps of Engineers
District Engineer

Enclosure

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202-2733

APR 16 1990

Mr. T. R. Vogt, P.E.
Acting Chief, Planning Section
COE, Ft. Worth District
P.O. Box 17300
Ft. Worth, Texas 76102-0300

Dear Mr. Vogt:

In accordance with our responsibilities under Section 309 of the Clean Air Act, and the National Environmental Policy Act, the Region 6 Office of the Environmental Protection Agency has completed the review of your Draft Environmental Assessment (EA), and Draft Finding of No Significant Impact (FNSI) on the proposed flood control improvements along Shoal Creek in Austin, Texas.

As described in the EA, the Army Corps of Engineers proposes to reduce potential flood damage by enlarging the channel for 11,400 feet in the upstream portion of Shoal Creek; 3,200 feet of a Shoal Creek tributary, Hancock Creek; and construct two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The EA states that the tunnel systems will spare the removal of large bottomland hardwoods. The proposed plan appears to have substantially less overall adverse impacts on riparian forests as well as resident aquatic life within Shoal Creek than any of the comprehensive channel plans. It also meets the criteria as specified by Section 404(b)(1) of the Clean Water Act. The Draft FNSI concluded that the proposed action will not have a significant adverse affect on the quality of the human environment. Accordingly, we have no objection to the proposed project.

Thank you for the opportunity to provide comments

Sincerely yours,

Norm Thomas
Chief
Federal Activities Branch (6E-F)

EXHIBIT 11

APPENDIX A

SHOAL CREEK
AUSTIN, TEXAS

PUBLIC INVOLVEMENT

Public involvement in the planning of this project began early in the study and has continued throughout. These activities involved discussions with Congressional interests and representatives of the city of Austin, as well as the general public. There have been numerous staff level meetings, informal workshops, as well as a public meeting. Coordination has been maintained throughout the study with the U. S. Fish and Wildlife Service, as well as the State Historic Preservation Officer. The formal activities are summarized below.

June 23, 1987 A Public Notice of Study Findings was sent to Federal, State, and local officials, as well as the local residents and environmental groups.

August 12, 1987 A Public Meeting was held in Austin to present the results of the studies. Several major concerns were expressed. These concerns centered on the location of the tunnel outlets on Lake Austin, and the potential water quality impacts on Lake Austin.

October 27, 1987 The Austin city council was presented the results of a revision to the report in a council work session. The revisions to the plan included moving the tunnel outlet location on one tunnel and changing the entire location on the other tunnel.

October 13, 1988 The city of Austin provided a Letter of Intent.

October 1988 - May 1990 Numerous staff level meetings have been held with city of Austin officials to discuss the alternative tunnel alignments, the location of the tunnel outlets, and the water quality issues.

Another Public Notice of the study findings and a Public Meeting will be held in 1990. This coordination will be included in the final report.

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

REPLY TO
ATTENTION OF:

June 23, 1987

Planning Division

LOCAL FLOOD PROTECTION PROJECT
SHOAL CREEK
AUSTIN, TEXAS

PUBLIC NOTICE

Interested parties are hereby notified that the District Engineer, Fort Worth District, proposes flood control improvements along Shoal Creek in Austin, Texas.

Statutory Authority. This public notice is being issued to all interested parties in accordance with the provisions of Public Law 91-190, The National Environmental Policy Act of 1969. Authority for the proposed action is contained in the Flood Control Act of 1936, Section 6; Committee on Commerce Resolution of 1936; River and Harbor Act of 1937, Section 4; and River and Harbor Act of 1945, Section 6.

History and Purpose. By letter sent July 1981, the Mayor of Austin requested that the Fort Worth District, U.S. Army Corps of Engineers, investigate flooding problems along Shoal Creek and to recommend potential solutions. Under authority of Section 205 of the Flood Control Act of 1948, a reconnaissance study was made which showed that enough damageable property existed in the flood plain to warrant more detailed studies to determine the Federal interest for construction of a flood control project. Results of the reconnaissance study were forwarded to higher Corps offices for review and, subsequently, detailed project study was initiated under specific authorization for Colorado River and Tributaries under the Flood Control Act of 1936 and subsequent acts. This public notice presents the results of detailed studies and provides the recommendations of the Fort Worth District for public review and comment.

Proposed Action. Initially, several basic structural and nonstructural measures were studied. Structural measures included detention reservoirs, channel improvements, levees, and tunnels. Basic nonstructural measures included flood proofing, zoning, permanent evacuation, and flood warning. After the initial analysis, seven alternatives were investigated in detail. The seven alternatives included a "no action" plan, three channel plans, and three channel-tunnel combination plans. The "no action" alternative simply pertains to the probable future condition of the study area in the absence of a structural or nonstructural plan to reduce damages. The Recommended Plan is one of the channel-tunnel combination plans.

The Recommended Plan for flood damage reduction basically consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek; a 30-foot bottom width, grass-lined channel on Hancock Creek (Shoal Creek tributary); and two separate 18.5-foot diameter tunnel systems in the upper and middle reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends 12,265 linear feet (2.3 miles) downstream just north of Northwest Park. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall at Dry Creek near Lake Austin. The lower tunnel system consists of an intake on Shoal Creek near 45th Street, an intake on Hancock Creek just upstream of Burnet Road, and a single outfall in an unnamed tributary near Laguna Gloria Art Center near Lake Austin. All tunnel intakes are accompanied with diversion structures, and both outfalls are accompanied with stilling basins. Each diversion dam will be perforated with a 42-inch diameter conduit to pass flows downstream. The grass-lined channel on Hancock Creek lies upstream of Burnet Road for 700 feet with a concrete drop structure and stilling basin at the upper end.

The Recommended Plan also includes a linear recreation plan. The recreation plan includes a 1.7-mile trail for hiking, biking, and nature study, and park benches. Recreation average annual benefits are $38,700, and annual charges are $34,400 which includes $11,800 for operation, maintenance, and replacement. The recreational benefit-to-cost ratio is 1.1 to 1.0. The annual charges and annual benefits of the recreation are included in the cost for the Recommended Plan.

The Recommended Plan has a first cost of $90,500,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of $41,800 annually; and average annual benefits of $11,827,500. The Recommended Plan is the NED plan. The attached project map depicts the Recommended Plan.

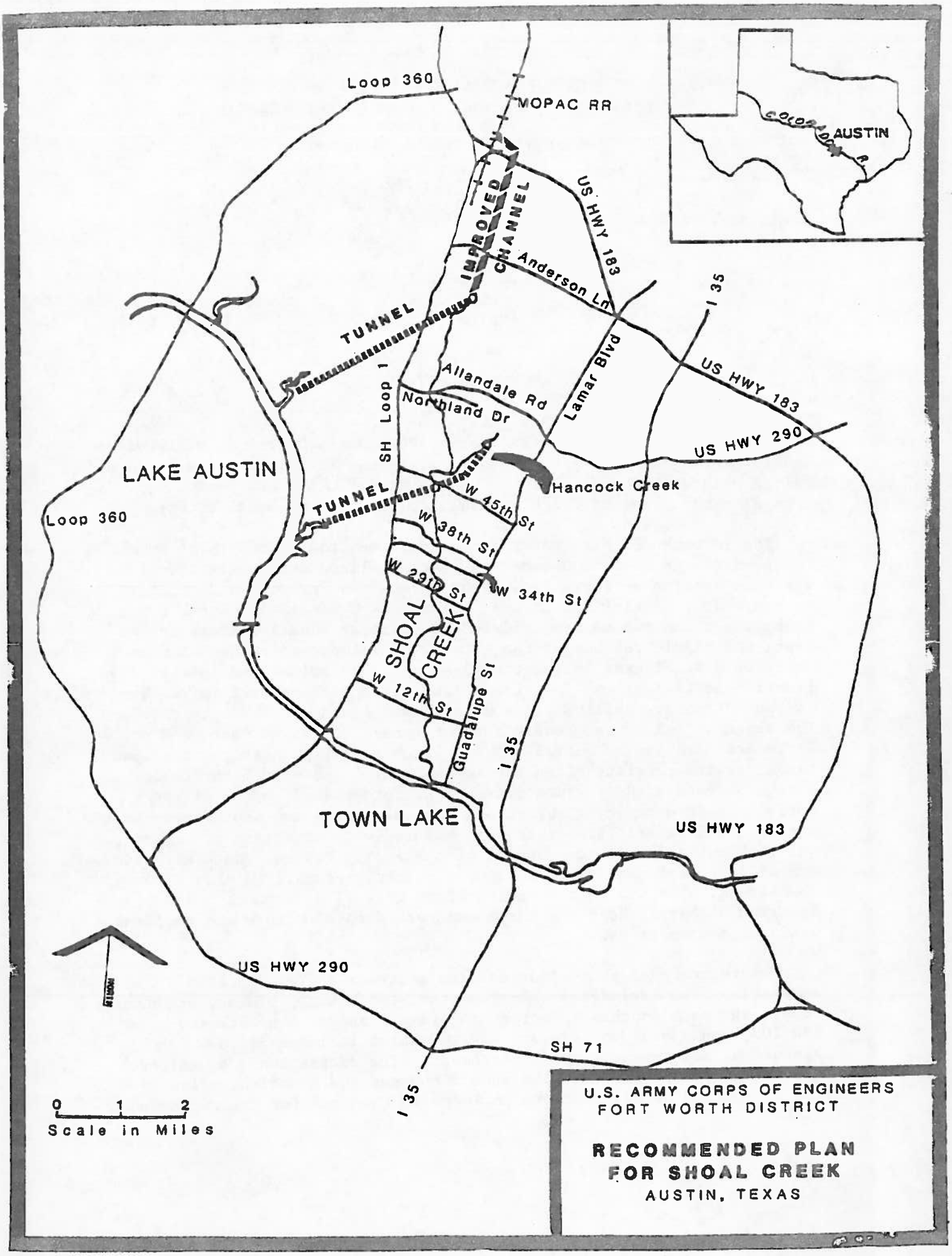
The environmental aspects of this project and its alternatives were considered in a preliminary Environmental Assessment prepared by the Fort Worth District. A preliminary Finding Of No Significant Impact has been made which, pending receipt of public comments to the contrary, will be finalized at the end of the comment period. A preliminary Section 404(b)(1) evaluation has been completed and is attached as an exhibit to the preliminary Environmental Assessment. A public meeting will be scheduled at a later date. Copies of the Environmental Assessment are available for review in the Austin Central Library, 800 Guadalupe Street, or the North Village Library, 2135 West Anderson Lane, Austin, Texas. Copies may also be obtained from the Fort Worth District, Planning Division, P.O. Box 17300, Fort Worth, Texas 76102-0300, upon request.

Any comments on the proposed action should be received no later than 30 days from the date of this notice. If no comments significantly

affecting the decision are received by that date, it will be considered that there are no overriding objections. For further information, contact Mr. Bob Shelton, Planning Division, Fort Worth District, at (817) 334-2095.

A. J. Genetti, Jr.
Colonel, CE
District Engineer

Enclosure


Loop 360
MOPAC RR
AUSTIN
IMPROVED CHANNEL
US HWY 183
Anderson Ln
I 35
TUNNEL
Allandale Rd
Lamar Blvd
US HWY 183
Northland Dr
SH Loop 1
US HWY 290
LAKE AUSTIN
Hancock Creek
TUNNEL
W 45th St
Loop 360
W 38th St
W 29th St
W 34th St
SHOAL CREEK
W 12th St
Guadalupe St
I 35
TOWN LAKE
US HWY 183
US HWY 290
SH 71
I 35
0 1 2
Scale in Miles
U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT
RECOMMENDED PLAN
FOR SHOAL CREEK
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:

July 30, 1987

Planning Division

LOCAL FLOOD PROTECTION PROJECT
SHOAL CREEK
AUSTIN, TEXAS

PUBLIC NOTICE

The U.S. Army Corps of Engineers, Fort Worth District, will hold a public meeting at 7:00 p.m., Wednesday, August 12, 1987, at Saint John's United Methodist Church, 2410 Allendale Road, in Austin, Texas, regarding the proposed flood control improvements to Shoal Creek.

The recommended plan for flood damage reduction consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek above Greenlawn Parkway; a 30-foot bottom width, grass-lined channel on Hancock Creek (Shoal Creek tributary); and two separate 18.5-foot diameter tunnel systems in the upper and middle reaches of the stream. The improved channel begins north of U.S. Highway 183 at the MOPAC railroad bridge and ends 12,265 linear feet (2.3 miles) downstream just north of Northwest Park. Two 11-foot diameter conduits allow water passage under U.S. Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall at Dry Creek near Lake Austin. The lower tunnel system consists of an intake on Shoal Creek near 45th Street, an intake on Hancock Creek just upstream of Burnet Road, and a single outfall in an unnamed tributary near Laguna Gloria Art Center near Lake Austin. All tunnel intakes are accompanied with diversion structures, and both outfalls are accompanied with stilling basins. Each diversion dam will be perforated with a 42-inch diameter conduit to pass flows downstream. The 700 feet of grass-lined channel on Hancock Creek lies upstream of Burnet Road and has a concrete drop structure and stilling basin at the upper end.

The recommended plan also includes a linear recreation plan. The recreation plan includes a 1.7-mile trail for hiking, biking, and nature study, and park benches. Recreation average annual benefits are $38,700, and annual charges are $34,400 which includes $11,800 for operation, maintenance, and replacement. The recreational benefit-to-cost ratio is 1.1 to 1.0. The annual charges and annual benefits of the recreation development are included in the cost for the recommended plan.

The recommended plan has a first cost of $90,500,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of $41,800 annually; and average annual benefits of $11,827,500. Copies of the report and environmental assessment are available for review in the Austin Central Library, 800 Guadalupe Street, or the North Village Library, 2135 West Anderson Lane, Austin, Texas.

Since a public meeting is scheduled after the end of the original 30-day comment period indicated in the Public Notice dated June 23, 1987, the comment period is being extended one week after the public meeting to August 19, 1987.

A. J. Genetti, Jr.
Colonel, CE
District Engineer

City of Austin
Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-2000

October 13, 1988

Colonel John E. Schaufelberger
Corps of Engineers
Department of the Army
Fort Worth District
P. O. Box 17300
Fort Worth, TX 76102-0300

LETTER OF INTENT

The City Council of the City of Austin approved the attached resolution on July 14, 1988 declaring its support for the flood control proposals for Shoal Creek described in the Draft Interim Report provided under letter dated June 23, 1987, and the Supplemental Report provided under letter dated January 12, 1988.

We request that the report be finalized and submitted to Congress for construction funding consideration.

Please contact me if you need additional information.

John L. Ware
Acting City Manager

JLW:GEO:rd

RESOLUTION

WHEREAS, the United States Corps of Engineers has developed flood reduction proposals for Shoal Creek which is located within the City of Austin's jurisdiction; and,

WHEREAS, a letter of intent to participate from the City of Austin is a prerequisite for congressional consideration for additional funding to support plan development for said flood control proposals; and,

WHEREAS, the letter of intent does not commit the City of Austin financially to said flood control project; Now, therefore,

BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF AUSTIN:

That the City Council authorizes the Acting City Manager of the City of Austin, or his designee, to execute a letter of intent from the City of Austin to the United States Corps of Engineers, supporting the Shoal Creek Flood control project.

ADOPTED: July 14, 1988. **ATTEST:** James E. Aldridge
James E. Aldridge
City Clerk

DLG:jba
Ltr.Int/Shoal Creek

THE STATE OF TEXAS ⁑

COUNTY OF TRAVIS ⁑

I, Betty G. Brown, Deputy City Clerk of the City of Austin, Texas, do hereby certify that the foregoing instrument is a true and correct copy of a Resolution consisting of 1 page(s), adopted by the City Council of the City of Austin, Texas, at a regular meeting on the 14th day of July, 19 88, and appears of record in Minute Book 64 of the Minutes of said City Council.

As on file in the City Clerk's Office this the 21st day, of July, 19 88.

Betty G. Brown

Betty G. Brown, Deputy City Clerk
CITY OF AUSTIN, TEXAS

City of Austin

Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-2000

October 13, 1988

Colonel John E. Schaufelberger
Corps of Engineers
Department of the Army
Fort Worth District
P. O. Box 17300
Fort Worth, TX 76102-0300

RE: Shoal Creek Flood Control Proposals

Dear Colonel Schaufelberger:

This is to request that the Corps investigate minimizing stormwater diversion into Lake Austin for the two 14 foot diameter tunnels plus channel improvements option presented in the Supplemental Report dated January, 1988.

As presented in the above noted report, the proposed wier height for the upper tunnel diversion is very near the flow line elevation. This configuration would allow stormwater diversion into Lake Austin for all storms which produce runoff rates greater than 50 cfs at the diversion point. An analysis performed by the City indicates that if the weir elevation can be raised such that diversion does not occur until runoff exceeds 1000 cfs, the cumulative impact on Lake Austin water quality is greatly reduced. The enclosed water quality impact study prepared by the City presents quantitative information on Lake Austin water quality effects which will result from the proposed diversions and the beneficial effects of preventing flows from smaller, more frequent storms from entering the upper diversion tunnel.

Spill thresholds at the upper tunnel above 1000 cfs will result in additional reductions in Lake Austin water quality impact. Therefore, we request that the Corps investigate a range of diversion threshold options for the upper tunnel to determine what effect they will have on flood protection and project economics. This information will be of extreme value to the City in its decision process for continued support of this option.

I am providing the attached report prepared by our Department of Environmental Protection on the impact of the proposed Shoal Creek diversions on Lake Austin and Town Lake for your information. If you need additional technical information, please contact George E. Oswald at (512) 499-7102.

Sincerely,

John L. Ware
Acting City Manager

JLW:GEO:rd

Attachment

Impacts of the Proposed Shoal Creek Diversions on the Water Quality of Lake Austin and Town Lake

In order to resolve Shoal Creek flooding problems, the U.S. Corps of Engineers (COE) proposed streamflow diversions from Shoal Creek to Town Lake and/or Lake Austin. The COE Shoal Creek draft report presents two tunnel diversion options. The first option is a combination of two diversions, from Shoal Creek at Northwest Park to Lake Austin below Bull Creek and from Shoal Creek at 24th Street to Town Lake below the MoPac Bridge. Each of the diversions will be controlled by an ogee weir; part of the Shoal Creek stormwater will spill over the weir to a 14 ft. diameter connecting tunnel. The second option is a single diversion from Shoal Creek at 24th Street to Town Lake below MoPac Bridge. This diversion will be accomplished with an ogee weir and an 18.5 ft. diameter connecting tunnel.

This report discusses the impacts of the diversions on both lakes' water quality. The following conclusions were drawn based on the operation of a mass balance computer model and the information presented in the referenced studies (References 1-7).

Conclusions for Diversion Option 1 (Two Tunnels)

1. There will typically be 10 diversions or spills per year from Shoal Creek to Lake Austin, with an average diversion of about 135 acre-feet per storm. It is estimated that there will be a spill from Shoal Creek

whenever a 1 inch or larger rainfall occurs (Table 1).

2. The water quality of Shoal Creek at Northwest Park is slightly better than that of Shoal Creek at 12th Street. As compared to the runoff water of Lake Austin watershed, however, the Shoal Creek water at Northwest Park is of significantly lower quality. (Table 2).

3. In addition, Shoal Creek water contains significantly higher concentrations of toxic substances such as As, Cu, Pb, Zn, PCB, chlordane, DDD, DDE, DDT, diazinon, Pyrene, and PAHs. The runoff water form the Lake Austin watershed has less or little of such toxics.

4. The effects of Shoal Creek stormwater diversion on Lake Austin (between Metropolitan Park and Tom Miller Dam) water quality are significant in several cases. The percent increases of pollutant concentrations and loads vary for different pollutants as shown in Table 3. The effects are most significant in the fall months (September and October). A simulation of daily lake operation without Shoal Creek Diversion indicates that it takes about 2-3 days for the lake to return to its normal cleaner condition after there is stormwater runoff entering the lake (resulting from a 1-3 inch rainfall). With Shoal Creek diversion or spill this dilution time will lengthen to about 3-5 days.

5. The Shoal Creek diversion has adverse effects on the beneficial uses of Lake Austin water (Table 5). The lake volumetric capacity will be reduced at a greater rate due to the increase of sediment load. The growth of algae in the lake may be accelerated due to the increases in

phosphorous. The cost of chemicals for potable water treatment will be increased due to the increases of various urban runoff pollutants. The recreational use of lake water will be affected due to the increases of turbidity and fecal coliform. The threat to aquatic life will be increased due to the presence of more toxic substances.

6. In general, the Shoal Creek diversion to Town Lake has no adverse effect on the Town Lake water quality. The diversion, however, entering Town Lake upstream from Green water treatment plant will affect the water quality of the intake and in turn may increase the cost of treatment slightly.

Conclusions for Diversion Option 2 (Single Tunnel at 24th Street)

1. There will be typically 10 diversions (or spills) per year from Shoal Creek to Town Lake with an average spill of about 250 acre-feet per storm.

2. In general, the diversion has no adverse effect on Town Lake water quality. The overall lake water quality may be improved slightly because the diverted water is somewhat cleaner than it would be if this water passed through the entire Shoal Creek watershed. However, the water quality between the MoPac Bridge and the mouth of Shoal Creek will be poorer for short periods after diversions. It is estimated that the diversion will affect the intake of Green water treatment plant and may slightly increase the City's overall water treatment cost.

Recommendation

The diversion structures and water quality in Shoal Creek at Northwest Park should be studied further before a decision can be made on implementation. The diversion option 1 should be considered only if the impact of the diversions on Lake Austin water quality is minimized. This can be achieved by minimizing the amounts of spills. In other words, the crests of the diversion weirs should be raised to a level such that only water which would otherwise cause flooding will be diverted to the lakes. As an example, the impacts of the diversion on Lake Austin water quality will be insignificant should the weir crests be raised so that only flows exceeding 1,000 cfs will spill over to the diversion channel (Table 6) In this case, the total annual diversion is estimated to be about 330 acre-feet. Only 1-2 spills may occur during a year.

It is recommended that the hydrology of the Shoal Creek should be further studied and the design of the diversion structure be modified. Diversion structure designs should be investigated that minimize the release of floatable materials. In addition, a water quality monitoring station should be installed on Shoal Creek at the Northwest Park site. This sampler will monitor the water quality of the streamflow to be diverted to Lake Austin in order to better quantify the impacts of the diversion.

Details of Study

1. Water Quality and Quantity of Shoal Creek Diversion

According to the COE study (Reference 1), the first option is to divert Shoal Creek streamflow through two separate tunnels, one 14 ft. diameter upper tunnel from Northwest Park to Lake Austin below Bull Creek, and one 14 ft. diameter lower tunnel from 24th Street to Town Lake below the MoPac bridge. The diversion structures are designed in such manner that the low flow would remain in Shoal Creek and the flow above 50 cfs would spill to the diversion tunnels. The annual spills were estimated to be about 1,350 and 1,610 acre-feet, respectively. The second option proposes one 18.5 ft. diversion tunnel from 24th Street to Town Lake below the MoPac bridge. The annual spills were estimated to be about 2,520 acre-feet. The reasons for selecting the "50 cfs" criterion are not documented in the COE Shoal Creek report. This flow rate appears to be so low that some of the streamflows resulting from higher frequency storms where little or no flooding occurs may spill to the diversion tunnels.

The COE (Reference 1) reported that there will be an average of 9 spills to Lake Austin from Northwest Park. We estimate that each of the associated rainfall events will have a rainfall depth of greater than 1 inch. As evidenced by the daily rainfall record for Shoal Creek between 1975 and 1985, on an annual basis there are typically seven 1-2 inch rainfall events, two 2-3 inch rainfall events, and at least one greater than 3 inch rainfall event. In other words, there should be about 10 rainfall events which have rainfall depths of 1 inch or more. Therefore, this study assumes that the Shoal Creek diversion for each location consists of 10 spills corresponding to 10 specified rainfall events. The volume of a diversion is the total runoff generated from

the rainfall minus the volume of low flow discharge (i.e., 50 cfs). The total runoff can be estimated from the runoff-rainfall relationships developed for Shoal Creek (Reference 3). The diversions were distributed over 12 months in accordance with the distribution of the rainfall events. Table 1 is a listing of the diversions for each month for each location.

The water quality of streamflow at the diversion points was estimated using the data developed by the City's NURP and creek modeling studies (references 3-4). The modeling study analyzed the water quality of the June 16, 1981 storm for Shoal Creek at 12th Street. This storm represents a 1-year frequency rainfall event. Immediately before this event there were 5 consecutive days of rainfall which generated 6 inches of runoff. Therefore, the pollutant concentrations of this storm can best represent the diluted conditions of water quality for larger storms. The pollutant concentrations of this storm were further adjusted for the size of the drainage area to obtain concentration values for the water at the diversion points. This adjustment was made by incorporating the NURP Study data. This estimation is a conservative approach and concentrations may be higher under certain circumstances. Table 2 compares the stormwater pollutant concentrations among three locations. The Lake Austin watershed concentration values were derived from Bull Creek and Lake Austin data which have been presented in various City of Austin reports (References 3-6).

2. Water Quality Impacts on Lake Austin

A simple mass balance computer model was prepared for studying the impacts of diversions on Lake Austin and Town Lake water quality. The model divides the lake into three sections(i.e., Mansfield Dam to Metropolitan Park to Tom Miller Dam to Longhorn Dam) and simulates the lake operation from upstream to downstream sections. The simulation assumes average flow and runoff conditions for each section, performing mass balance accounting of water and pollutants with the alternative scenarios of including and excluding Shoal Creek diversions. A monthly operation run was made for 12 consecutive months. A daily operation run was made for the month of October. Data for the operations, such as lake storage, Lake Travis release, evaporation, water treatment intake, runoff quantity and quality were obtained from various City of Austin studies (References 3-6). The following descriptions are based mainly on the results of the computer simulations.

(1) Conventional parameters

Eight conventional urban runoff pollutant parameters were considered in the computer simulation. These includes organics (BOD, TOC), total suspended solids (TSS), nutrients (NO3, NH3, TKN, TP), and fecal coliform (FCOL). The results of the simulations are presented in Tables 3-4. Table 3 summarizes the effects of option 1 diversions on Lake Austin and Town Lake water quality. Table 4 summarizes the effects of option 2 diversions on Town Lake water quality. The effects are expressed in the percent differences of pollutant load or concentration between two scenarios i.e., with and without diversions. For lake

Austin between Metropolitan Park and Tom Miller Dam, the change in concentration or load for TSS, TP, and fecal coliform due to the Shoal Creek diversion are the most significant, i.e, the annual average increases are 8,9, and 31 percent, respectively. On a storm to storm basis, the increases per storm (or per each Shoal Creek spill) are about 16, 30, and 70 percent, with the worst case in October to be about 24, 54, and 117 percent, respectively. Since the water turbidity is known to be directly proportional to the TSS concentration by examining the USGS/City of Austin hydrologic data (Reference 2), the increase of turbidity in Lake Austin will be similar to the increase of TSS. On the other hand, the annual average increases in load for NO3, NH3, TKN, BOD, and TOC are much less, only about 0-2 percent. The increases per each spill for these pollutants are about 1-5 percent, with the worst case occurring in October, about 2-9 percent.

The Shoal Creek diversions will enter Lake Austin about 1,000 feet below Bull Creek, upstream from the City's Davis and Ullrich water treatment plant intake points. The change in intake water quality is estimated to be about the same as that of lake storage.

For Town Lake, the change in average lake water quality due to option 1 and option 2 diversions is not significant. The annual average decreases in concentrations for the described pollutants are within 3 percent. However, the concentrations for the upstream part of the lake may be significantly higher for short periods. The Shoal Creek diversions enter Town Lake below MoPac bridge, upstream from the City's Green water treatment plant. The increases in pollutant concentrations

for the intake of the treatment plant are similar to those of Davis and Ullrich plants.

(2) Toxic parameters

Only some of the metals such as As, Cu, Fe, Pb, and Zn are included in the computer simulation. The data for other toxic parameters such as PCB, DDD, DDE, DDT, diazinon, PAH, Chlordane, and Pyrene are insufficient and cannot be included in the computer simulation.

For Lake Austin between Metropolitan Park and Tom Miller Dam, the annual average load or concentration increases of the dissolved metals due to the Shoal Creek spills are about 0-2 percent. The average 'per spill' increases for these parameters are about 1-9 percent. The toxic substances other than metals were examined using the USGS/City of Austin hydrologic data, and the results of NURP and lake modeling studies (references 2,4, and 7). As compared to Bull Creek, a major tributary of Lake Austin, the Shoal Creek water has significantly higher concentrations of DDT, DDD, DDE, PCB, and diazinon, (based on the USGS/City of Austin hydrologic data of 1975-81). In addition, the Shoal Creek water contains PAH, Pyrene, and Chlordane of which little or none have been found in Bull Creek and Lake Austin water. The referenced studies indicate that the concentrations of the toxics in Town Lake bottom sediment are significantly higher than those in Lake Austin. This further implies that the Shoal Creek spills will carry substantially more toxics into Lake Austin than normally occur in its associated watershed.

The changes in metal concentrations in Town Lake (as a whole) due to option 1 and option 2 diversions are not significant. The concentration changes of other toxics due to the diversions cannot be quantitatively evaluated, however, these were estimated to be small.

3. Impacts on lake beneficial use

As described, the Shoal Creek diversions will not significantly change the overall water quality of Town Lake and therefore the diversions should not affect its beneficial use significantly. However, the cost of water treatment for Green water treatment plant may be increased as there will be increases in concentrations of some urban runoff pollutants at the water intake. According to the NURP study (reference 4), the cost of chemicals for treating hardness and alkalinity is about 90 percent of the total chemical cost for treatment of the lake water. The cost of chemicals for treating urban runoff pollutants is about 10 percent of the total chemical cost. The ratio of the total chemical cost to the total treatment cost is unclear. As the Shoal Creek diversions do not change the hardness and alkalinity of the lake water and the effect of concentration increases of other pollutants on treatment costs is less, the cost increase for water treatment due to the Shoal Creek diversions is considered insignificant.

On the other hand, the effects of the option 1 Shoal Creek diversion on Lake Austin beneficial use are significant. The Shoal Creek diversions will carry significantly more sediment to the lake as evidenced by the

increase of lake TSS load in the computer simulation. This will accelerate the reduction in lake capacity. The increase in TP is also significant. According to the lake modeling study (reference 4), nitrogen and phosphorus are two macronutrients for algae. The existence of more phosphorous in the lake may increase the rate of algae growth.

High bacteria concentrations and turbidity are threats to the human activities in the lake. There will be significant increases in bacteria (fecal coliform) and turbidity in the lake due to Shoal Creek diversions and this will affect the lake's recreation uses. The computer simulation indicates that, for each Shoal Creek spill it takes about 1-2 additional days for the lake water to return to its normal condition. The load increases of TSS, fecal coliform, and other urban runoff pollutants in Lake Austin also increase the cost of water treatment for both Davis and Ullrich water treatment plants. Using the cost of total chemicals (for water treatment) as a standard, the cost increase due to the Shoal Creek diversions is estimated to be less than 1 percent. The presence of more toxic materials in Lake Austin can be a threat to aquatic life. The compounds which pose a potential threat to indigenous aquatic life are chlordane, DDT plus metabolitics, and possibly PAHs. These substances have been frequently found in the Shoal Creek water (Reference 7).

4. Alternative Consideration

The impact of the diversions on Lake Austin water quality can be significantly reduced by minimizing the volume of spills to the lake.

For example, if the diversion structures are be modified so that only the flow exceeding 1000 cfs will spill to Lake Austin. The volume of spill is the total storm runoff minus the volume of runoff flow occurring below or equal to 1,000 cfs. Based on the storm rainfall-runoff data of Shoal Creek at Northwest Part (1975-1984), it is estimated that on the average only 1-2 rainfall events per year may produce runoff exceeding 1,000 cfs and result in significant amount of spills. The May 18, 1982 storm was picked to represent such an event. The rainfall and runoff depths for the storm are 5.47 and 2.36 inches, respectively. The peak flow of the runoff is 2,930 cfs. The volume of flow exceeding 1,000 cfs is about 165 acre-feet. Assuming this storm occurs twice a year (in May and October), the spills to Lake Austin will be about 330 acre-feet per year. The impacts of the spills on Lake Austin water quality were studied using the described mass balance model. The impacts are insignificant. On an annual basis, the percent differences of pollutant loads or concentrations for all parameters between the two scenarios (i.e., with or without spills) are within 2.4 percent as shown in Table 6. The percent differences for TSS, TP, and fecal coliform are 1.6, 2.4, and 1.70 percents, respectively. The percent differences for all other parameters are within 0.5 percent.

References

1. U.S. Corps of Engineers. "Shoal Creek Draft Interim Report", June 1987, Supplemental Report, January 1988.

2. U.S. Geological Survey. "Hydrologic Data for Urban Studies in the Austin, Texas Metropolitan Area", prepared in cooperation with the City of Austin, 1975-1985.

3. City of Austin. "Stormwater Quality Modeling for Austin Creeks", November 1984, Updated data, March 1988.

4. Engineering Science and City of Austin. "Final Report of the Nationwide Urban Runoff Program in Austin, Texas", January 1983.

5. City of Austin. "Lake Austin/Town Lake Water Quality Data Analysis", February 1984.

6. City of Austin. "Water Quality Data Analysis for Colorado River", September 1986.

7. Armstrong, N.E., et al. "Water Quality Studies in Lake Austin and Town Lake", Draft Report, March 1987.

TABLE 1

Estimated Diversions (or spills) from Shoal Creek to Lake Austin and Town lake

ITIONS	Location of Diversion	Estimated diversions* or spills in Acres-feet												
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
I	NW PARK (14-ft Tunnel)	0	0	50	198	308	198	50	50	198	198	50	50	1,350
	24th street (14-ft Tunnel)	50	50	70	198	328	218	70	70	198	218	70	70	1,610
II	24th Street (18.5-ft tunnel)	80	80	160	300	400	360	120	120	300	360	120	120	2,520

* The monthly diversion values were estimated using the Shoal Creek rainfall and daily runoff flow data (1975 -1985)

TABLE 2

Comparisons of Storm Water Quality Between Shoal Creek and Lake Austin Watershed

Stormwater Pollutant Concentrations *

LOCATION	BOD	TOC	TSS	NO3	NH3	TKN	TP	F. COL	As	Cu	Pb	Zn
Shoal Creek at 12th St.	12	32	1,800	0.47	0.13	3.70	1.4	66,700	7	5	5	11
Shoal Creek at NW Park **	6	18	900	0.67	0.17	1.60	1.0	30,000	5	4	4	8
Lake Austin Watershed	3	15	400	0.30	0.10	1.60	0.15	4,000	1	2	1	5

* The units of pollutant concentrations:

Fecal Coliform in Col./100 ml
As, Cu, Pb, and Zn in Ug/l
BOD, TOC, TSS, NO3, NH3, TKN, TP in mg/l

** The pollutant Concentrations of Shoal Creek at Northwest Park were derived for one-year frequency or larger storms.

TABLE 3, Percent Increase of Load or Concentration for Lake Austin and Town Lake
Due to Option 1 Shoal Creek Diversions **

Lake Austin between Metropolitan park and Tom Miller Dam

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	0.00	0.00	0.52	1.58	1.82	0.94	0.59	0.61	2.91	3.24	1.99	1.81	1.34
TSS	0.00	0.00	1.82	9.84	8.46	4.57	4.97	6.70	34.31	12.28	9.66	8.14	8.40
NO3	0.00	0.00	0.49	0.98	1.39	0.70	0.35	0.33	1.56	3.06	1.53	1.45	0.99
NH3	0.00	0.00	0.34	0.73	1.10	0.56	0.27	0.26	1.22	2.48	1.22	1.15	0.78
TKN	0.00	0.00	0.13	0.43	0.51	0.27	0.16	0.17	0.80	0.91	0.55	0.51	0.37
TP	0.00	0.00	3.51	9.76	11.45	5.86	3.68	3.77	18.17	21.01	12.69	11.43	8.45
TOC	0.00	0.00	0.39	1.03	1.28	0.66	0.39	0.39	1.86	2.42	1.39	1.27	0.92
CU	0.00	0.00	0.27	0.65	0.85	0.45	0.24	0.23	1.11	1.71	0.92	0.86	0.61
FE	0.00	0.00	0.13	0.38	0.59	0.31	0.16	0.16	0.74	1.26	0.65	0.61	0.42
PB	0.00	0.00	0.32	0.65	0.95	0.48	0.24	0.23	1.12	2.09	1.02	0.96	0.67
ZN	0.00	0.00	0.07	0.12	0.18	0.09	0.04	0.04	0.19	0.43	0.20	0.19	0.13
AS	0.00	0.00	0.75	1.27	1.85	0.93	0.43	0.40	1.88	4.30	2.05	1.95	1.32
F COL	0.00	0.00	9.14	58.76	46.99	25.53	42.50	133.89	1206.58	64.76	53.41	43.90	31*

* Geometric mean

Town Lake

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	-1.20	-1.12	-1.59	-2.45	-3.48	-1.43	-0.70	-1.41	-5.11	-10.18	-2.31	-2.93	-2.83
TSS	-1.31	-1.03	-1.98	-3.58	-4.72	-1.54	-0.64	-2.96	-8.23	-13.90	-1.99	-3.08	-3.75
NO3	0.19	0.21	0.10	0.29	0.51	0.57	0.34	0.22	0.26	0.47	0.93	0.54	0.39
NH3	0.12	0.46	0.25	0.45	0.75	0.74	0.41	0.29	0.52	1.27	1.47	1.08	0.67
TKN	-0.71	-0.77	-0.87	-1.21	-1.88	-0.80	-0.42	-0.65	-2.65	-5.76	-1.56	-1.92	-1.60
TP	-0.37	-0.30	-1.43	-1.94	-2.08	0.76	0.37	-0.69	-4.43	-9.05	0.40	-1.17	-1.66
TOC	-0.63	-0.65	-0.96	-1.34	-1.95	-0.66	-0.34	-0.67	-2.92	-6.07	-1.26	-1.74	-1.60
CU	-0.16	-0.23	-0.41	-0.50	-0.73	-0.11	-0.05	-0.20	-1.21	-2.82	-0.32	-0.70	-0.62
FE	-0.12	-0.20	-0.30	-0.42	-0.69	-0.18	-0.09	-0.20	-1.09	-2.66	-0.44	-0.75	-0.60
PB	-0.14	-0.20	-0.40	-0.50	-0.71	-0.10	-0.04	-0.19	-1.14	-2.64	-0.29	-0.64	-0.58
ZN	-0.04	-0.06	-0.11	-0.12	-0.16	-0.02	-0.01	-0.04	-0.23	-0.63	-0.07	-0.17	-0.14
AS	-0.22	-0.25	-0.68	-0.74	-0.91	0.04	0.04	-0.21	-1.49	-3.80	-0.11	-0.77	-0.76
F COL	-0.34	-0.25	-1.69	-2.44	-2.25	2.27	0.87	-0.89	-5.82	-11.17	1.22	-0.96	-1.79

** Two 14 ft. diameter tunnels; an upper tunnel from Northwest Park to lake Austin below Bull Creek, and a lower tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 4, Percent Decrease (Increase) of Load or Concentration for Town Lake Due to Option 2 Shoal Creek Diversions *

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	-1.92	-1.80	-1.82	-1.71	-1.82	-1.64	-0.87	-1.38	-3.20	-7.16	-2.48	-2.77	-2.38
TSS	-2.09	-1.65	-1.90	-2.24	-2.26	-2.35	-1.11	-2.84	-4.30	-8.10	-2.57	-2.77	-2.85
NO3	0.31	0.33	0.38	0.36	0.41	0.34	0.21	0.23	0.65	1.45	0.62	0.63	0.49
NH3	0.51	0.74	0.65	0.49	0.56	0.48	0.27	0.30	0.89	2.61	1.04	1.22	0.81
TKN	-1.14	-1.23	-1.08	-0.89	-1.01	-0.85	-0.48	-0.64	-1.75	-4.31	-1.58	-1.83	-1.40
TP	-0.59	-0.48	-0.57	-0.63	-0.57	-0.61	-0.27	-0.57	-0.96	-2.13	-0.69	-0.75	-0.73
TOC	-1.00	-1.04	-1.02	-0.90	-0.98	-0.84	-0.47	-0.65	-1.68	-3.94	-1.44	-1.60	-1.30
CU	-0.25	-0.36	-0.35	-0.28	-0.32	-0.27	-0.15	-0.19	-0.52	-1.36	-0.52	-0.59	-0.43
FE	-0.19	-0.32	-0.32	-0.27	-0.33	-0.28	-0.16	-0.19	-0.55	-1.51	-0.58	-0.67	-0.45
PB	-0.23	-0.31	-0.33	-0.28	-0.31	-0.26	-0.15	-0.17	-0.49	-1.26	-0.50	-0.55	-0.40
ZN	-0.07	-0.10	-0.09	-0.06	-0.07	-0.06	-0.03	-0.03	-0.10	-0.30	-0.13	-0.14	-0.10
AS	-0.35	-0.40	-0.41	-0.33	-0.33	-0.30	-0.15	-0.19	-0.50	-1.38	-0.54	-0.60	-0.46
F COL	-0.54	-0.40	-0.53	-0.72	-0.59	-0.76	-0.28	-0.98	-1.02	-2.09	-0.64	-0.67	-0.77

* One 18.5 ft. diameter tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 5, The Effects of the Proposed shoal Creek diversion on
The beneficial Use of Lake Austin Water

Type of Use	* Adverse Impact
Drinking Water	1. Cost Increase of chemicals for water treatment. 2. Increase of concentrations of toxic substances in water and lake bottom sediment.
Aquatic Life	Increase of potential treat to aquatic life by carrying specific toxic substances (Chlorine, Copper, PAHs, Pylene, and DDT components.)
Recreation	1. Increase of bacteria (fecal coliform.) 2. Increase of turbidity (i.e. decreasing the number of days for recreation.)
Limiting Algal Growth	Increase of nutrients such as TP, NO3, and NH3 (accelerate algae growth)

* One 18.5 ft. diameter tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 6, Percent Increase of Load or Concentration for Lake Austin
Due to Reduced Shoal Creek Diversions (see recommendation)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	0.00	0.00	0.00	0.00	0.92	0.06	0.01	0.00	0.00	2.35	0.78	0.26	0.36
TSS	0.00	0.00	0.00	0.00	4.29	0.27	0.06	0.01	0.00	8.98	3.83	1.18	1.55
NO3	0.00	0.00	0.00	0.00	0.71	0.04	0.00	0.00	0.00	2.24	0.61	0.21	0.32
NH3	0.00	0.00	0.00	0.00	0.56	0.03	0.00	0.00	0.00	1.82	0.49	0.17	0.26
TKN	0.00	0.00	0.00	0.00	0.26	0.02	0.00	0.00	0.00	0.65	0.20	0.07	0.10
TP	0.00	0.00	0.00	0.00	5.81	0.35	0.04	0.00	0.00	15.44	5.09	1.67	2.37
TOC	0.00	0.00	0.00	0.00	0.65	0.04	0.00	0.00	0.00	1.75	0.54	0.18	0.26
CU	0.00	0.00	0.00	0.00	0.43	0.03	0.00	0.00	0.00	1.24	0.36	0.12	0.18
FE	0.00	0.00	0.00	0.00	0.30	0.02	0.00	0.00	0.00	0.91	0.25	0.09	0.13
PB	0.00	0.00	0.00	0.00	0.48	0.03	0.00	0.00	0.00	1.53	0.41	0.14	0.22
ZN	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.00	0.00	0.32	0.08	0.03	0.04
AS	0.00	0.00	0.00	0.00	0.94	0.05	0.01	0.00	0.00	3.17	0.83	0.29	0.44
FC	0.00	0.00	0.00	0.00	23.83	1.50	0.51	0.17	0.04	47.61	21.46	6.44	1.70*

* Geometric mean

July 1989
A Supplement to
The City of Austin's June 1988 Report

Impacts of the Proposed Shoal Creek Diversions on the Water Quality of Lake Austin and Town Lake

As was discussed in the City of Austin's June 1988 report, the first design option (with diversions to both Lake Austin and Town Lake) should be considered only if the impact of the diversions on Lake Austin water quality is minimized. The water quality impact can be minimized if the crest of the diversion weir at the Northwest Park is raised so that only flows which would otherwise cause unacceptable flooding will spill over to the diversion channel. This supplementary report further develops relationships between the water quality impacts and the flow rate criterion (i.e., the diversion scenarios).

Using the hydrologic data of Shoal Creek at Northwest Park, such as daily rainfall, daily streamflow, and storm rainfall-runoff analyses (Reference 1), the volumes of diversions corresponding to each diversion scenario were estimated. This correlation is given in Table 1. The existing water quality conditions of Lake Austin and Shoal Creek were described in the COA's June 1988 report. These estimates were further reviewed and found to be adequate (Reference 2). By knowing the volumes and water quality of various diversions, the Lake Austin water quality impacts corresponding to these diversions can be determined through the operation of a simple mass balance computer model. This model was described in the COA's June 1988 report. The current report presents the following findings based on the model operation.

1. Table 2 and Figure 1 present a general relationship between the Lake Austin water quality impact and the diversion scenario. On an annual basis, the average percent increase of pollutant load or concentration for 13 pollutants decreases geometrically with increasing flow rate requirements (or decreasing diversion). It can be seen that the impact begins to decrease dramatically if the diversions occur only when the flows exceed about 1,000-1,500 cfs. This effect can be further verified by comparing the lake pollutant concentrations among various diversion scenarios as shown in Table 3.

2. Table 4 presents the relationship between the Lake Austin water quality impact and the diversion scenario for the most impacted month, i.e., month of May or October when most of the diversions occur. On a monthly basis, the average percent increase of load or concentration of 13 pollutants decreases geometrically with increasing flow rate requirement (or decreasing diversion). The lake pollutant concentrations for various diversion scenarios were compared with those of the existing or no diversion condition as shown in Tables 5-6. Again, the comparison indicates that the water quality impact begins to decrease significantly if the diversions occur only when the flows exceed about 1,000 - 1,500 cfs.

3. Table 7 presents Lake Austin's water quality conditions after a storm event (a storm of greater than 3-inch rainfall). For the extreme case of October when the Lake Travis release is low and the storm runoff from Lake Austin watershed is high, the impact of the Shoal Creek diversion can be significant. As shown in Table 7, increases of

concentrations for TSS, TP, and fecal coliform are significant even if the diversions occur only when the flows exceed 1,000 cfs. Theoretically, for the same storm event, no diversion will occur if the Shoal Creek spill is allowed only when the flow exceeds 1,500 cfs (see Table 1). In this case, no lake impact should exist. On the other hand, there will be some diversions if the same storm occurs in May and the Shoal Creek spill is allowed when the flow exceeds 1,500 cfs (Table 1). Nevertheless, the impact of these diversions on Lake Austin's water quality is not significant. As shown in Table 8, the pollutant concentrations in Lake Austin are significantly less than those of the October event (Table 7). Under the 1,500 cfs scenario, the concentration increases due to the Shoal Creek diversion are minor.

References

1. U.S. Geological Survey. Hydrologic Data for Urban Studies in the Austin, Texas Metropolitan Area. Prepared in cooperation with the City of Austin, 1975-1984.

2. City of Austin. Stormwater Pollutant Loading Characteristics for Various Land Uses in the Austin Area. Prepared by the Environmental Planning Division, Environmental and Conservation Department, July 1988.

TABLE 1

VOLUME OF DIVERSION TO LAKE AUSTIN ASSOCIATED WITH
EACH DIVERSION SCENARIO

	Diversion to Lake Austin Occurs when Shoal Creek Flow Exceeds:					
Months	50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500cfs
Jan	0	0	0	0	0	0
Feb	0	0	0	0	0	0
Mar	50*	0	0	0	0	0
Apr	50	0	0	0	0	0
May	506	384	165	86	21	5
Jun	148	0	0	0	0	0
Jul	0	0	0	0	0	0
Aug	0	0	0	0	0	0
Sept	50	0	0	0	0	0
Oct	446	384	165	0	0	0
Nov	50	0	0	0	0	0
Dec	50	0	0	0	0	0
Total	1,350	768	330	86	21	5

* Values are volumes of diversions in acre-feet.

TABLE 2

PERCENT INCREASE OF LOAD OR CONCENTRATION IN LAKE AUSTIN DUE TO SHOAL CREEK DIVERSION (ANNUAL AVERAGE CONDITION)

Months	Diversion to Lake Austin Occurs when Shoal Creek Flow Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500 cfs
BOD	1.3*	1.0	0.4	0.1	0.001	0
TSS	8.5	5.6	1.6	0.3	0.04	0.02
NO_3	1.0	0.7	0.3	0	0	0
NH_3	0.8	0.7	0.3	0	0	0
TKN	0.4	0.3	0.1	0	0	0
TP	8.6	6.5	2.4	0.3	0.03	0
TOC	0.9	0.7	0.3	0	0	0
Cu	0.6	0.4	0.2	0	0	0
Fe	0.4	0.3	0.1	0	0	0
Pb	0.7	0.5	0.2	0	0	0
Zn	0.1	0.1	0.0	0	0	0
As	1.3	1.0	0.4	0	0	0
Fe. Col.	31.0	6.0	1.7	1.2	0.2	0.06
Average	4.3	1.8	0.6	0.15	0.02	0.01

* Values of percent increase, e.g., 1.3%.

TABLE 3

POLLUTANT CONCENTRATIONS IN LAKE AUSTIN BELOW BULL CREEK
UNDER DIFFERENT DIVERSION SCENARIOS
(ANNUAL AVERAGE CONDITION)

Months	With No Diversion	Diversion to Lake Austin Occurs when Shoal Creek Flow Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500 cfs
BOD	0.89*	0.91	0.90	0.90	0.89	0.89	0.89
TSS	37	40	39	38	37	37	37
NO_3	0.14	0.14	0.14	0.14	0.14	0.14	0.14
NH_3	0.046	0.047	0.047	0.047	0.046	0.046	0.046
TKN	0.68	0.68	0.68	0.68	0.68	0.68	0.68
TP	0.030	0.033	0.032	0.031	0.030	0.030	0.030
TOC	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Cu	1.25	1.26	1.26	1.25	1.25	1.25	1.25
Fe	13.30	13.40	13.40	13.30	13.30	13.30	13.30
Pb	1.17	1.18	1.18	1.17	1.17	1.17	1.17
Zn	6.07	6.07	6.07	6.07	6.07	6.07	6.07
As	1.0	1.02	1.01	1.0	1.0	1.0	1.0
Fe. Col.	230	326	290	256	233	231	230

* Values shown are annual average pollutant concentrations (including both baseflow and storm-event conditions). The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn, or As is 10^{-3} milligram per liter. The unit of all other parameters is milligram per liter.

TABLE 4

PERCENT INCREASE OF LOAD OR CONCENTRATION IN LAKE AUSTIN DUE TO SHOAL CREEK DIVERSION (WORST CASE: MONTH OF MAY OR OCTOBER)

Months	Diversion to Lake Austin Occurs when Shoal Creek Flow Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500 cfs
BOD	6.4*	5.5	2.4	0.5	0.10	0
TSS	25	21	9.0	2.2	0.60	0.13
NO_3	6.1	5.0	2.2	0.4	0.07	0
NH_3	5.0	4.0	1.8	0.2	0	0
TKN	1.8	1.3	0.7	0.2	0.04	0
TP	42	34	15	2.9	0.06	0
TOC	4.8	1.9	1.8	0.3	0.08	0.02
Cu	3.4	2.9	0.9	0.2	0.04	0.01
Fe	2.5	2.0	0.9	0.2	0.04	0.01
Pb	4.2	4.0	1.5	0.3	0.06	0.01
Zn	4.9	4.3	0.3	0.1	0.01	0.01
As	8.6	6.3	3.2	0.5	0.1	0.03
Fe. Col.	130	108	48	12	3.0	0.90
Average	19	15	6.8	1.5	0.3	0.1

* Values of percent increase, e.g., 6.4%.

TABLE 5

POLLUTANT CONCENTRATIONS IN LAKE AUSTIN BELOW BULL CREEK
UNDER DIFFERENT DIVERSION SCENARIOS
(ONE OF THE WORST CASES, THE MONTH OF MAY)

Pollutant	With No Diversion	With Shoal Creek Diversion when Flow Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500 cfs
BOD	0.92*	0.94	0.94	0.92	0.92	0.92	0.92
TSS	38	43	42	40	39	38	38
NO_3	0.141	0.144	0.143	0.142	0.142	0.141	0.141
NH_3	0.043	0.044	0.044	0.043	0.043	0.043	0.043
TKN	0.67	0.68	0.68	0.67	0.67	0.67	0.67
TP	0.031	0.037	0.036	0.033	0.032	0.032	0.031
TOC	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Cu	1.21	1.23	1.22	1.22	1.22	1.21	1.21
Fe	11.6	11.7	11.7	11.6	11.6	11.6	11.6
Pb	1.13	1.14	1.14	1.13	1.13	1.13	1.13
Zn	6.02	6.04	6.03	6.03	6.02	6.02	6.02
As	1.0	1.03	1.02	1.01	1.0	1.0	1.0
Fe. Col.	235	408	365	291	264	242	237

* Values shown are monthly average pollutant concentrations (including both baseflow and storm-event conditions). The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pu, Zn, or As is 10^{-3} milligram per liter. The unit of all other parameters is milligrams per liter.

TABLE 6

POLLUTANT CONCENTRATIONS IN LAKE AUSTIN BELOW BULL CREEK
UNDER DIFFERENT DIVERSION SCENARIOS
(ONE OF THE WORST CASES, THE MONTH OF OCTOBER)

Pollutant	With No Diversion	With Shoal Creek Diversion when Flow Exceeds: 50 cfs	500 cfs	1000 cfs	1500 cfs	2000 cfs	2500 cfs
BOD	1.15*	1.22	1.21	1.17	1.15	1.15	1.15
TSS	59	74	72	65	59	59	59
NO_3	0.148	1.157	0.155	0.151	0.148	0.148	0.148
NH_3	0.044	0.046	0.045	0.045	0.044	0.044	0.044
TKN	0.79	0.81	0.80	0.80	0.79	0.79	0.79
TP	0.039	0.056	0.054	0.046	0.040	0.039	0.039
TOC	4.8	5.0	4.9	4.9	4.8	4.8	4.8
Cu	1.35	1.40	1.39	1.37	1.35	1.35	1.35
Fe	12.3	12.6	12.5	12.4	12.3	12.3	12.3
Pb	1.17	1.22	1.21	1.19	1.17	1.17	1.17
Zn	6.0	6.1	6.0	6.0	6.0	6.0	6.0
As	1.0	1.09	1.07	1.03	1.0	1.0	1.0
Fe. Col.	394	904	827	582	394	394	394

* Values shown are monthly average pollutant concentrations (including both baseflow and storm-event conditions). The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn or As is 10^{-3} milligram per liter. The unit of all other parameters is milligram per liter.

TABLE 7

WATER QUALITY CONDITIONS OF LAKE AUSTIN BELOW BULL CREEK AFTER A STORM EVENT IN OCTOBER WITH AND WITHOUT SHOAL CREEK DIVERSIONS

	Without Diversions			With Diversions When Flow Exceeds 1,000 CFS		
Pollutant	Day of Storm	3 Days After Storm	7 Days After Storm	Day of Storm	3 Days After Storm	7 Days After Storm
BOD	1.23*	1.23	1.12	1.31	1.32	1.19
TSS	66	66	58	83	83	72
NO_3	0.15	0.15	0.15	0.16	0.16	0.16
NH_3	0.08	0.08	0.08	0.08	0.08	0.078
TKN	0.91	0.91	0.86	0.92	0.92	0.87
TP	0.033	0.033	0.03	0.051	0.051	0.046
TOC	5.0	5.0	4.6	5.2	5.2	4.8
Cu	2.18	2.18	2.0	2.21	2.21	2.03
Fe	30	30	28	30	30	28
Pb	1.96	1.96	1.83	2.0	2.0	1.86
Zn	6.02	6.82	6.70	6.86	6.86	6.74
As	1.0	1.0	1.0	1.10	1.10	1.08
Fe. Col	453	453	396	1,026	1,027	880

* Values shown are daily average pollutant concentrations. The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn, or As is 10^{-3} milligram per liter. The unit of all other parameters is milligrams per liter.

TABLE 8

WATER QUALITY CONDITIONS OF LAKE AUSTIN BELOW BULL CREEK AFTER A STORM EVENT IN MAY WITH AND WITHOUT SHOAL CREEK DIVERSIONS

	Without Diversions		With Diversions When Flow Exceeds 1,000 CFS		With Diversions When Flow Exceeds 1,500 CFS	
Pollutant	3 Days After Storm	7 Days After Storm	3 Days After Storm	7 Days After Storm	3 Days After Storm	7 Days After Storm
BOD	1.02*	0.82	1.05	0.84	1.04	0.83
TSS	54	36	60	39	57	38
NO_3	0.16	0.15	0.16	0.15	0.16	0.06
NH_3	0.07	0.07	0.06	0.07	0.07	0.06
TKN	0.82	0.71	0.83	0.71	0.82	0.71
TP	0.030	0.025	0.038	0.029	0.034	0.027
TOC	4.4	3.8	4.5	3.8	4.4	3.8
Cu	1.60	1.34	1.61	1.35	1.60	1.34
Fe	22.9	19.5	22.9	19.5	22.9	19.5
Pb	1.49	1.31	1.51	1.35	1.50	1.31
Zn	6.39	6.25	6.40	6.26	6.39	6.25
As	1.0	1.0	1.04	1.02	1.02	1.01
Fe. Col.	369	232	596	358	489	299

* Values shown are daily average pollutant concentrations. The unit of fecal coliform is colonies per 100 milliliter. The unit of Cu, Fe, Pb, Zn, or As is 10^{-3} milligram per liter. The unit of all other parameters is milligrams per liter.

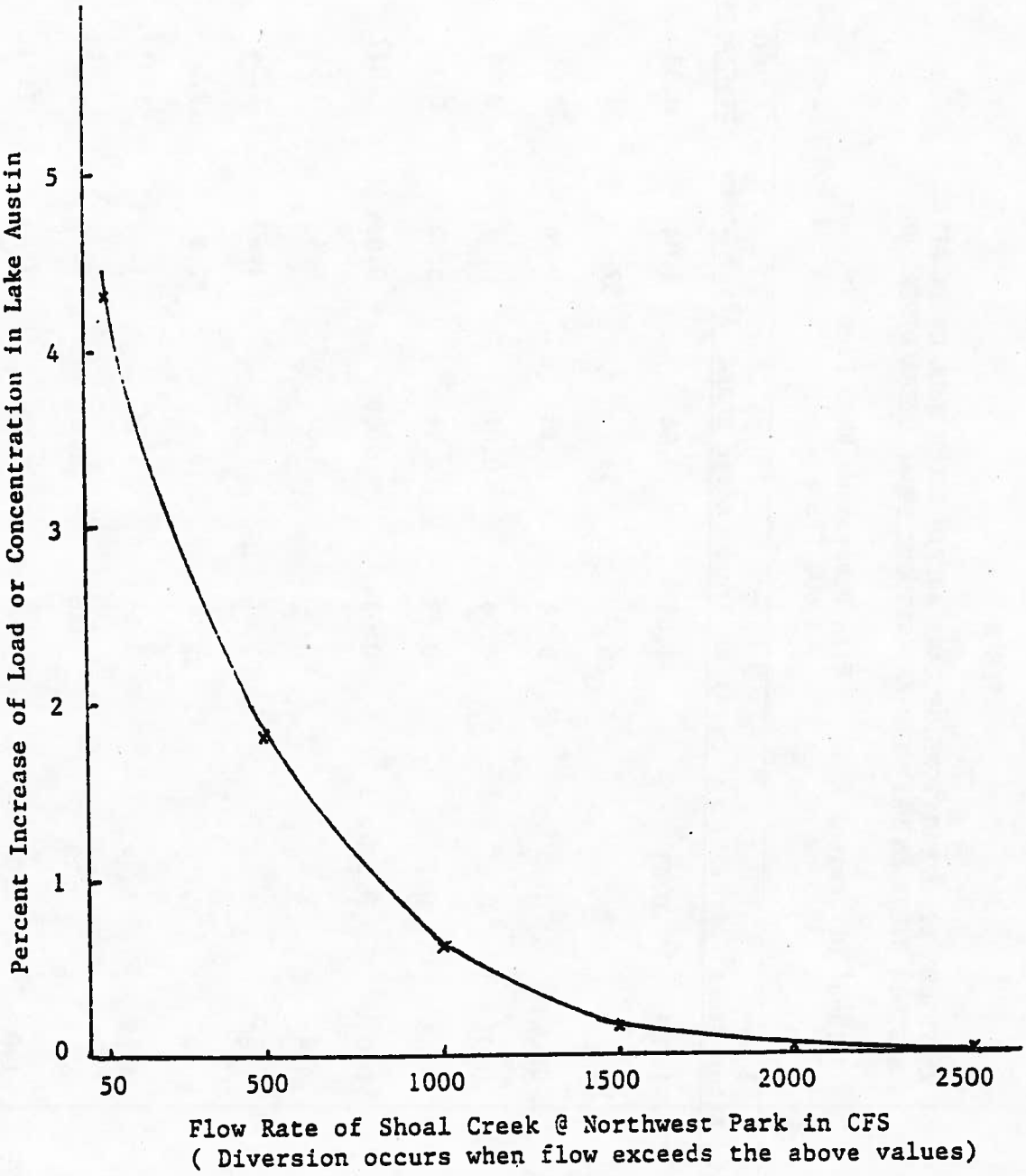


FIGURE 1. ANNUAL AVERAGE PERCENT INCREASE OF POLLUTANT LOAD OR CONCENTRATION IN LAKE AUSTIN BELOW BULL CREEK DUE TO SHOAL CREEK DIVERSION(AVERAGE INCREASE OF THIRTEEN POLLUTANTS)

Impacts of the Proposed Shoal Creek Diversions

on the Water Quality of Lake Austin and Town Lake

June 1988

In order to resolve Shoal Creek flooding problems, the U.S. Corps of Engineers (COE) proposed streamflow diversions from Shoal Creek to Town Lake and/or Lake Austin. The COE Shoal Creek draft report presents two tunnel diversion options. The first option is a combination of two diversions, from Shoal Creek at Northwest Park to Lake Austin below Bull Creek and from Shoal Creek at 24th Street to Town Lake below the MoPac Bridge. Each of the diversions will be controlled by an ogee weir; part of the Shoal Creek stormwater will spill over the weir to a 14 ft. diameter connecting tunnel. The second option is a single diversion from Shoal Creek at 24th Street to Town Lake below MoPac Bridge. This diversion will be accomplished with an ogee weir and an 18.5 ft. diameter connecting tunnel.

This report discusses the impacts of the diversions on both lakes' water quality. The following conclusions were drawn based on the operation of a mass balance computer model and the information presented in the referenced studies (References 1-7).

Conclusions for Diversion Option 1 (Two Tunnels)

1. There will typically be 10 diversions or spills per year from Shoal Creek to Lake Austin, with an average diversion of about 135 acre-feet per storm. It is estimated that there will be a spill from Shoal Creek

whenever a 1 inch or larger rainfall occurs (Table 1).

2. The water quality of Shoal Creek at Northwest Park is slightly better than that of Shoal Creek at 12th Street. As compared to the runoff water of Lake Austin watershed, however, the Shoal Creek water at Northwest Park is of significantly lower quality. (Table 2).

3. In addition, Shoal Creek water contains significantly higher concentrations of toxic substances such as As, Cu, Pb, Zn, PCB, chlordane, DDD, DDE, DDT, diazinon, Pyrene, and PAHs. The runoff water form the Lake Austin watershed has less or little of such toxics.

4. The effects of Shoal Creek stormwater diversion on Lake Austin (between Metropolitan Park and Tom Miller Dam) water quality are significant in several cases. The percent increases of pollutant concentrations and loads vary for different pollutants as shown in Table 3. The effects are most significant in the fall months (September and October). A simulation of daily lake operation without Shoal Creek Diversion indicates that it takes about 2-3 days for the lake to return to its normal cleaner condition after there is stormwater runoff entering the lake (resulting from a 1-3 inch rainfall). With Shoal Creek diversion or spill this dilution time will lengthen to about 3-5 days.

5. The Shoal Creek diversion has adverse effects on the beneficial uses of Lake Austin water (Table 5). The lake volumetric capacity will be reduced at a greater rate due to the increase of sediment load. The growth of algae in the lake may be accelerated due to the increases in

phosphorous. The cost of chemicals for potable water treatment will be increased due to the increases of various urban runoff pollutants. The recreational use of lake water will be affected due to the increases of turbidity and fecal coliform. The threat to aquatic life will be increased due to the presence of more toxic substances.

6. In general, the Shoal Creek diversion to Town Lake has no adverse effect on the Town Lake water quality. The diversion, however, entering Town Lake upstream from Green water treatment plant will affect the water quality of the intake and in turn may increase the cost of treatment slightly.

Conclusions for Diversion Option 2 (Single Tunnel at 24th Street)

1. There will be typically 10 diversions (or spills) per year from Shoal Creek to Town Lake with an average spill of about 250 acre-feet per storm.

2. In general, the diversion has no adverse effect on Town Lake water quality. The overall lake water quality may be improved slightly because the diverted water is somewhat cleaner than it would be if this water passed through the entire Shoal Creek watershed. However, the water quality between the MoPac Bridge and the mouth of Shoal Creek will be poorer for short periods after diversions. It is estimated that the diversion will affect the intake of Green water treatment plant and may slightly increase the City's overall water treatment cost.

Recommendation

The diversion structures and water quality in Shoal Creek at Northwest Park should be studied further before a decision can be made on implementation. The diversion option 1 should be considered only if the impact of the diversions on Lake Austin water quality is minimized. This can be achieved by minimizing the amounts of spills. In other words, the crests of the diversion weirs should be raised to a level such that only water which would otherwise cause flooding will be diverted to the lakes. As an example, the impacts of the diversion on Lake Austin water quality will be insignificant should the weir crests be raised so that only flows exceeding 1,000 cfs will spill over to the diversion channel (Table 6) In this case, the total annual diversion is estimated to be about 330 acre-feet. Only 1-2 spills may occur during a year.

It is recommended that the hydrology of the Shoal Creek should be further studied and the design of the diversion structure be modified. Diversion structure designs should be investigated that minimize the release of floatable materials. In addition, a water quality monitoring station should be installed on Shoal Creek at the Northwest Park site. This sampler will monitor the water quality of the streamflow to be diverted to Lake Austin in order to better quantify the impacts of the diversion.

Details of Study

1. Water Quality and Quantity of Shoal Creek Diversion

According to the COE study (Reference 1), the first option is to divert Shoal Creek streamflow through two separate tunnels, one 14 ft. diameter upper tunnel from Northwest Park to Lake Austin below Bull Creek, and one 14 ft. diameter lower tunnel from 24th Street to Town Lake below the MoPac bridge. The diversion structures are designed in such manner that the low flow would remain in Shoal Creek and the flow above 50 cfs would spill to the diversion tunnels. The annual spills were estimated to be about 1,350 and 1,610 acre-feet, respectively. The second option proposes one 18.5 ft. diversion tunnel from 24th Street to Town Lake below the MoPac bridge. The annual spills were estimated to be about 2,520 acre-feet. The reasons for selecting the "50 cfs" criterion are not documented in the COE Shoal Creek report. This flow rate appears to be so low that some of the streamflows resulting from higher frequency storms where little or no flooding occurs may spill to the diversion tunnels.

The COE (Reference 1) reported that there will be an average of 9 spills to Lake Austin from Northwest Park. We estimate that each of the associated rainfall events will have a rainfall depth of greater than 1 inch. As evidenced by the daily rainfall record for Shoal Creek between 1975 and 1985, on an annual basis there are typically seven 1-2 inch rainfall events, two 2-3 inch rainfall events, and at least one greater than 3 inch rainfall event. In other words, there should be about 10 rainfall events which have rainfall depths of 1 inch or more. Therefore, this study assumes that the Shoal Creek diversion for each location consists of 10 spills corresponding to 10 specified rainfall events. The volume of a diversion is the total runoff generated from

the rainfall minus the volume of low flow discharge (i.e., 50 cfs). The total runoff can be estimated from the runoff-rainfall relationships developed for Shoal Creek (Reference 3). The diversions were distributed over 12 months in accordance with the distribution of the rainfall events. Table 1 is a listing of the diversions for each month for each location.

The water quality of streamflow at the diversion points was estimated using the data developed by the City's NURP and creek modeling studies (references 3-4). The modeling study analyzed the water quality of the June 16, 1981 storm for Shoal Creek at 12th Street. This storm represents a 1-year frequency rainfall event. Immediately before this event there were 5 consecutive days of rainfall which generated 6 inches of runoff. Therefore, the pollutant concentrations of this storm can best represent the diluted conditions of water quality for larger storms. The pollutant concentrations of this storm were further adjusted for the size of the drainage area to obtain concentration values for the water at the diversion points. This adjustment was made by incorporating the NURP Study data. This estimation is a conservative approach and concentrations may be higher under certain circumstances. Table 2 compares the stormwater pollutant concentrations among three locations. The Lake Austin watershed concentration values were derived from Bull Creek and Lake Austin data which have been presented in various City of Austin reports (References 3-6).

2. Water Quality Impacts on Lake Austin

A simple mass balance computer model was prepared for studying the impacts of diversions on Lake Austin and Town Lake water quality. The model divides the lake into three sections(i.e., Mansfield Dam to Metropolitan Park to Tom Miller Dam to Longhorn Dam) and simulates the lake operation from upstream to downstream sections. The simulation assumes average flow and runoff conditions for each section, performing mass balance accounting of water and pollutants with the alternative scenarios of including and excluding Shoal Creek diversions. A monthly operation run was made for 12 consecutive months. A daily operation run was made for the month of October. Data for the operations, such as lake storage, Lake Travis release, evaporation, water treatment intake, runoff quantity and quality were obtained from various City of Austin studies (References 3-6). The following descriptions are based mainly on the results of the computer simulations.

(1) Conventional parameters

Eight conventional urban runoff pollutant parameters were considered in the computer simulation. These includes organics (BOD, TOC), total suspended solids (TSS), nutrients (NO3, NH3, TKN, TP), and fecal coliform (FCOL). The results of the simulations are presented in Tables 3-4. Table 3 summarizes the effects of option 1 diversions on Lake Austin and Town Lake water quality. Table 4 summarizes the effects of option 2 diversions on Town Lake water quality. The effects are expressed in the percent differences of pollutant load or concentration between two scenarios i.e., with and without diversions. For Lake

Austin between Metropolitan Park and Tom Miller Dam, the change in concentration or load for TSS, TP, and fecal coliform due to the Shoal Creek diversion are the most significant, i.e, the annual average increases are 8,9, and 31 percent, respectively. On a storm to storm basis, the increases per storm (or per each Shoal Creek spill) are about 16, 30, and 70 percent, with the worst case in October to be about 24, 54, and 117 percent, respectively. Since the water turbidity is known to be directly proportional to the TSS concentration by examining the USGS/City of Austin hydrologic data (Reference 2), the increase of turbidity in Lake Austin will be similar to the increase of TSS. On the other hand, the annual average increases in load for NO3, NH3, TKN, BOD, and TOC are much less, only about 0-2 percent. The increases per each spill for these pollutants are about 1-5 percent, with the worst case occurring in October, about 2-9 percent.

The Shoal Creek diversions will enter Lake Austin about 1,000 feet below Bull Creek, upstream from the City's Davis and Ullrich water treatment plant intake points. The change in intake water quality is estimated to be about the same as that of lake storage.

For Town Lake, the change in average lake water quality due to option 1 and option 2 diversions is not significant. The annual average decreases in concentrations for the described pollutants are within 3 percent. However, the concentrations for the upstream part of the lake may be significantly higher for short periods. The Shoal Creek diversions enter Town Lake below MoPac bridge, upstream from the City's Green water treatment plant. The increases in pollutant concentrations

for the intake of the treatment plant are similar to those of Davis and Ullrich plants.

(2) Toxic parameters

Only some of the metals such as As, Cu, Fe, Pb, and Zn are included in the computer simulation. The data for other toxic parameters such as PCB, DDD, DDE, DDT, diazinon, PAH, Chlordane, and Pyrene are insufficient and cannot be included in the computer simulation.

For Lake Austin between Metropolitan Park and Tom Miller Dam, the annual average load or concentration increases of the dissolved metals due to the Shoal Creek spills are about 0-2 percent. The average 'per spill' increases for these parameters are about 1-9 percent. The toxic substances other than metals were examined using the USGS/City of Austin hydrologic data, and the results of NURP and lake modeling studies (references 2,4, and 7). As compared to Bull Creek, a major tributary of Lake Austin, the Shoal Creek water has significantly higher concentrations of DDT, DDD, DDE, PCB, and diazinon, (based on the USGS/City of Austin hydrologic data of 1975-81). In addition, the Shoal Creek water contains PAH, Pyrene, and Chlordane of which little or none have been found in Bull Creek and Lake Austin water. The referenced studies indicate that the concentrations of the toxics in Town Lake bottom sediment are significantly higher than those in Lake Austin. This further implies that the Shoal Creek spills will carry substantially more toxics into Lake Austin than normally occur in its associated watershed.

The changes in metal concentrations in Town Lake (as a whole) due to option 1 and option 2 diversions are not significant. The concentration changes of other toxics due to the diversions cannot be quantitatively evaluated, however, these were estimated to be small.

3. Impacts on lake beneficial use

As described, the Shoal Creek diversions will not significantly change the overall water quality of Town Lake and therefore the diversions should not affect its beneficial use significantly. However, the cost of water treatment for Green water treatment plant may be increased as there will be increases in concentrations of some urban runoff pollutants at the water intake. According to the NURP study (reference 4), the cost of chemicals for treating hardness and alkalinity is about 90 percent of the total chemical cost for treatment of the lake water. The cost of chemicals for treating urban runoff pollutants is about 10 percent of the total chemical cost. The ratio of the total chemical cost to the total treatment cost is unclear. As the Shoal Creek diversions do not change the hardness and alkalinity of the lake water and the effect of concentration increases of other pollutants on treatment costs is less, the cost increase for water treatment due to the Shoal Creek diversions is considered insignificant.

On the other hand, the effects of the option 1 Shoal Creek diversion on Lake Austin beneficial use are significant. The Shoal Creek diversions will carry significantly more sediment to the lake as evidenced by the

increase of lake TSS load in the computer simulation. This will accelerate the reduction in lake capacity. The increase in TP is also significant. According to the lake modeling study (reference 4), nitrogen and phosphorus are two macronutrients for algae. The existence of more phosphorous in the lake may increase the rate of algae growth.

High bacteria concentrations and turbidity are threats to the human activities in the lake. There will be significant increases in bacteria (fecal coliform) and turbidity in the lake due to Shoal Creek diversions and this will affect the lake's recreation uses. The computer simulation indicates that, for each Shoal Creek spill it takes about 1-2 additional days for the lake water to return to its normal condition. The load increases of TSS, fecal coliform, and other urban runoff pollutants in Lake Austin also increase the cost of water treatment for both Davis and Ullrich water treatment plants. Using the cost of total chemicals (for water treatment) as a standard, the cost increase due to the Shoal Creek diversions is estimated to be less than 1 percent. The presence of more toxic materials in Lake Austin can be a threat to aquatic life. The compounds which pose a potential threat to indigenous aquatic life are chlordane, DDT plus metabolitics, and possibly PAHs. These substances have been frequently found in the Shoal Creek water (Reference 7).

4. Alternative Consideration

The impact of the diversions on Lake Austin water quality can be significantly reduced by minimizing the volume of spills to the lake.

For example, if the diversion structures are be modified so that only the flow exceeding 1000 cfs will spill to Lake Austin. The volume of spill is the total storm runoff minus the volume of runoff flow occurring below or equal to 1,000 cfs. Based on the storm rainfall-runoff data of Shoal Creek at Northwest Part (1975-1984), it is estimated that on the average only 1-2 rainfall events per year may produce runoff exceeding 1,000 cfs and result in significant amount of spills. The May 18, 1982 storm was picked to represent such an event. The rainfall and runoff depths for the storm are 5.47 and 2.36 inches, respectively. The peak flow of the runoff is 2,930 cfs. The volume of flow exceeding 1,000 cfs is about 165 acre-feet. Assuming this storm occurs twice a year (in May and October), the spills to Lake Austin will be about 330 acre-feet per year. The impacts of the spills on Lake Austin water quality were studied using the described mass balance model. The impacts are insignificant. On an annual basis, the percent differences of pollutant loads or concentrations for all parameters between the two scenarios (i.e., with or without spills) are within 2.4 percent as shown in Table 6. The percent differences for TSS, TP, and fecal coliform are 1.6, 2.4, and 1.70 percents, respectively. The percent differences for all other parameters are within 0.5 percent.

References

1. U.S. Corps of Engineers. "Shoal Creek Draft Interim Report", June 1987, Supplemental Report, January 1988.

2. U.S. Geological Survey. "Hydrologic Data for Urban Studies in the Austin, Texas Metropolitan Area", prepared in cooperation with the City of Austin, 1975-1985.

3. City of Austin. "Stormwater Quality Modeling for Austin Creeks", November 1984, Updated data, March 1988.

4. Engineering Science and City of Austin. "Final Report of the Nationwide Urban Runoff Program in Austin, Texas", January 1983.

5. City of Austin. "Lake Austin/Town Lake Water Quality Data Analysis", February 1984.

6. City of Austin. "Water Quality Data Analysis for Colorado River", September 1986.

7. Armstrong, N.E., et al. "Water Quality Studies in Lake Austin and Town Lake", Draft Report, March 1987.

TABLE 1

Estimated Diversions (or spills) from Shoal Creek to Lake Austin and Town lake

OPTIONS	Location of Diversion	Estimated diversions* or spills in Acres-feet												
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
I	NW PARK (14-ft Tunnel)	0	0	50	198	308	198	50	50	198	198	50	50	1,350
	24th street (14-ft Tunnel)	50	50	70	198	328	218	70	70	198	218	70	70	1,610
II	24th Street (18.5-ft tunnel)	80	80	160	300	400	360	120	120	300	360	120	120	2,520

* The monthly diversion values were estimated using the Shoal Creek rainfall and daily runoff flow data (1975 -1985)

TABLE 2

Comparisons of Storm Water Quality Between Shoal Creek and Lake Austin Watershed

Stormwater Pollutant Concentrations *

LOCATION	BOD	TOC	TSS	NO3	NH3	TKN	TP	F. COL	As	Cu	Pb	Zn
Shoal Creek at 12th St.	12	32	1,800	0.47	0.13	3.70	1.4	66,700	7	5	5	11
Shoal Creek at NW Park **	6	18	900	0.67	0.17	1.60	1.0	30,000	5	4	4	8
Lake Austin Watershed	3	15	400	0.30	0.10	1.60	0.15	4,000	1	2	1	5

* The units of pollutant concentrations:
Fecal Coliform in Col./100 ml
As, Cu, Pb, and Zn in Ug/l
BOD, TOC, TSS, NO3, NH3, TKN, TP in mg/l

** The pollutant Concentrations of Shoal Creek at Northwest Park were derived for one-year frequency or larger storms.

TABLE 3, Percent Increase of Load or Concentration for Lake Austin and Town Lake
Due to Option 1 Shoal Creek Diversions **

Lake Austin between Metropolitan park and Tom Miller Dam

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	0.00	0.00	0.52	1.58	1.82	0.94	0.59	0.61	2.91	3.24	1.99	1.81	1.34
TSS	0.00	0.00	1.82	9.84	8.46	4.57	4.97	6.70	34.31	12.28	9.66	8.14	8.40
NO3	0.00	0.00	0.49	0.98	1.39	0.70	0.35	0.33	1.56	3.06	1.53	1.45	0.99
NH3	0.00	0.00	0.34	0.73	1.10	0.56	0.27	0.26	1.22	2.48	1.22	1.15	0.78
TKN	0.00	0.00	0.13	0.43	0.51	0.27	0.16	0.17	0.80	0.91	0.55	0.51	0.37
TP	0.00	0.00	3.51	9.76	11.45	5.86	3.68	3.77	18.17	21.01	12.69	11.43	8.45
TOC	0.00	0.00	0.39	1.03	1.28	0.66	0.39	0.39	1.86	2.42	1.39	1.27	0.92
CU	0.00	0.00	0.27	0.65	0.85	0.45	0.24	0.23	1.11	1.71	0.92	0.86	0.61
FE	0.00	0.00	0.13	0.38	0.59	0.31	0.16	0.16	0.74	1.26	0.65	0.61	0.42
PB	0.00	0.00	0.32	0.65	0.95	0.48	0.24	0.23	1.12	2.09	1.02	0.96	0.67
ZN	0.00	0.00	0.07	0.12	0.18	0.09	0.04	0.04	0.19	0.43	0.20	0.19	0.13
AS	0.00	0.00	0.75	1.27	1.85	0.93	0.43	0.40	1.88	4.30	2.05	1.95	1.32
F COL	0.00	0.00	9.14	58.76	46.99	25.53	42.50	133.89	1206.58	64.76	53.41	43.90	31*

* Geometric mean

Town Lake

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	-1.20	-1.12	-1.59	-2.45	-3.48	-1.43	-0.70	-1.41	-5.11	-10.18	-2.31	-2.93	-2.83
TSS	-1.31	-1.03	-1.98	-3.58	-4.72	-1.54	-0.64	-2.96	-8.23	-13.90	-1.99	-3.08	-3.75
NO3	0.19	0.21	0.10	0.29	0.51	0.57	0.34	0.22	0.26	0.47	0.93	0.54	0.39
NH3	0.32	0.46	0.25	0.45	0.75	0.74	0.41	0.29	0.52	1.27	1.47	1.08	0.67
TKN	-0.71	-0.77	-0.87	-1.21	-1.88	-0.80	-0.42	-0.65	-2.65	-5.76	-1.56	-1.92	-1.60
TP	-0.37	-0.30	-1.43	-1.94	-2.08	0.76	0.37	-0.69	-4.43	-9.05	0.40	-1.17	-1.66
TOC	-0.63	-0.65	-0.96	-1.34	-1.95	-0.66	-0.34	-0.67	-2.92	-6.07	-1.26	-1.74	-1.60
CU	-0.16	-0.23	-0.41	-0.50	-0.73	-0.11	-0.05	-0.20	-1.21	-2.82	-0.32	-0.70	-0.62
FE	-0.12	-0.20	-0.30	-0.42	-0.69	-0.18	-0.09	-0.20	-1.09	-2.66	-0.44	-0.75	-0.60
PB	-0.14	-0.20	-0.40	-0.50	-0.71	-0.10	-0.04	-0.19	-1.14	-2.64	-0.29	-0.64	-0.58
ZN	-0.04	-0.06	-0.11	-0.12	-0.16	-0.02	-0.01	-0.04	-0.23	-0.63	-0.07	-0.17	-0.14
AS	-0.22	-0.25	-0.68	-0.74	-0.91	0.04	0.04	-0.21	-1.49	-3.80	-0.11	-0.77	-0.76
F COL	-0.34	-0.25	-1.69	-2.44	-2.25	2.27	0.87	-0.89	-5.82	-11.17	1.22	-0.96	-1.79

** Two 14 ft. diameter tunnels; an upper tunnel from Northwest Park to lake Austin below Bull Creek, and a lower tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 4, Percent Decrease (Increase) of Load or Concentration for Town Lake
Due to Option 2 Shoal Creek Diversions *

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	-1.92	-1.80	-1.82	-1.71	-1.82	-1.64	-0.87	-1.38	-3.20	-7.16	-2.48	-2.77	-2.38
TSS	-2.09	-1.65	-1.90	-2.24	-2.26	-2.35	-1.11	-2.84	-4.30	-8.10	-2.57	-2.77	-2.85
NO3	0.31	0.33	0.38	0.36	0.41	0.34	0.21	0.23	0.65	1.45	0.62	0.63	0.49
NH3	0.51	0.74	0.65	0.49	0.56	0.48	0.27	0.30	0.89	2.61	1.04	1.22	0.81
TKN	-1.14	-1.23	-1.08	-0.89	-1.01	-0.85	-0.48	-0.64	-1.75	-4.31	-1.58	-1.83	-1.40
TP	-0.59	-0.48	-0.57	-0.63	-0.57	-0.61	-0.27	-0.57	-0.96	-2.13	-0.69	-0.75	-0.73
TOC	-1.00	-1.04	-1.02	-0.90	-0.98	-0.84	-0.47	-0.65	-1.68	-3.94	-1.44	-1.60	-1.30
CU	-0.25	-0.36	-0.35	-0.28	-0.32	-0.27	-0.15	-0.19	-0.52	-1.36	-0.52	-0.59	-0.43
FE	-0.19	-0.32	-0.32	-0.27	-0.33	-0.28	-0.16	-0.19	-0.55	-1.51	-0.58	-0.67	-0.45
PB	-0.23	-0.31	-0.33	-0.28	-0.31	-0.26	-0.15	-0.17	-0.49	-1.26	-0.50	-0.55	-0.40
ZN	-0.07	-0.10	-0.09	-0.06	-0.07	-0.06	-0.03	-0.03	-0.10	-0.30	-0.13	-0.14	-0.10
AS	-0.35	-0.40	-0.41	-0.33	-0.33	-0.30	-0.15	-0.19	-0.50	-1.38	-0.54	-0.60	-0.46
F COL	-0.54	-0.40	-0.53	-0.72	-0.59	-0.76	-0.28	-0.98	-1.02	-2.09	-0.64	-0.67	-0.77

* One 18.5 ft. diameter tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 5, The Effects of the Proposed shoal Creek diversion on
The beneficial Use of Lake Austin Water

Type of Use	Adverse Impact
Drinking Water	1. Cost Increase of chemicals for water treatment. 2. Increase of concentrations of toxic substances in water and lake bottom sediment.
Aquatic Life	Increase of potential threat to aquatic life by carrying specific toxic substances (Chlorine, Copper, PAHs, Pylene, and DDT components.)
Recreation	1. Increase of bacteria (fecal coliform.) 2. Increase of turbidity (i.e. decreasing the number of days for recreation.)
Limiting Algal Growth	Increase of nutrients such as TP, NO3, and NH3 (accelerate algae growth)

* One 18.5 ft. diameter tunnel from 24th street to Town Lake below MoPac Bridge.

TABLE 6, Percent Increase of Load or Concentration for Lake Austin
Due to Reduced Shoal Creek Diversions (see recommendation)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
BOD	0.00	0.00	0.00	0.00	0.92	0.06	0.01	0.00	0.00	2.35	0.78	0.26	0.36
TSS	0.00	0.00	0.00	0.00	4.29	0.27	0.06	0.01	0.00	8.98	3.83	1.18	1.55
NO3	0.00	0.00	0.00	0.00	0.71	0.04	0.00	0.00	0.00	2.24	0.61	0.21	0.32
NH3	0.00	0.00	0.00	0.00	0.56	0.03	0.00	0.00	0.00	1.82	0.49	0.17	0.26
TKN	0.00	0.00	0.00	0.00	0.26	0.02	0.00	0.00	0.00	0.65	0.20	0.07	0.10
TP	0.00	0.00	0.00	0.00	5.81	0.35	0.04	0.00	0.00	15.44	5.09	1.67	2.37
TOC	0.00	0.00	0.00	0.00	0.65	0.04	0.00	0.00	0.00	1.75	0.54	0.18	0.26
CU	0.00	0.00	0.00	0.00	0.43	0.03	0.00	0.00	0.00	1.24	0.36	0.12	0.18
FE	0.00	0.00	0.00	0.00	0.30	0.02	0.00	0.00	0.00	0.91	0.25	0.09	0.13
PB	0.00	0.00	0.00	0.00	0.48	0.03	0.00	0.00	0.00	1.53	0.41	0.14	0.22
ZN	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.00	0.00	0.32	0.08	0.03	0.04
AS	0.00	0.00	0.00	0.00	0.94	0.05	0.01	0.00	0.00	3.17	0.83	0.29	0.44
FC	0.00	0.00	0.00	0.00	23.83	1.50	0.51	0.17	0.04	47.61	21.46	6.44	1.70*

* Geometric mean

City of Austin

Founded by Congress, Republic of Texas 1839
Transportation & Public Services, P.O. Box 1088, Austin, Texas 78767-8839
Administrative Offices: One Texas Center, 505 Barton Springs Road Telephone 512/499-705

April 5, 1990

Michael J. Mocek, P.E.
Chief, Planning Division
Department of the Army
Fort Worth District, Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Mr. Mocek:

You had requested a "Financial Capability Statement" to be prepared by the City of Austin which would address the City's financial participation in the Shoal Creek Flood Control Project. In response, I have attached the requested worksheet completed with data that may be used to evaluate the project.

The City funds its share of flood control improvements through the issuance of general obligation bonds. The authority to issue this debt, according to the City Charter, must come from the citizens. Currently, there is no additional authority to issue debt for Shoal Creek. In addition, there are no current plans to obtain additional funding authority for Shoal Creek from the Austin electorate.

The Austin City Council's recently adopted Financial Policies include a provision whereby general obligation bond sales are limited to $25 million per year. At that rate, it will take four to five years before current unissued authority is depleted. Due to the extent to which the City funded the Shoal Creek project in 1982 and 1984 (approximately $15 million), and the extent to which there is a need and public demand for flood control improvements in other areas of the City, it is unlikely that the additional authority will be obtained in the next few years.

However, the City's financial policies are subject to change as the local economic condition improves. Should Council policies change so as to allow the issuance of debt for additional projects, then the proposed Shoal Creek project could be considered for additional funding authority in the future. In addition, the separation of the project into four phases increases the City's ability to provide its share of funding on a longer-term, ongoing basis. In that regard, it is important that the City and Corps of Engineers continue to work toward implementation of the project.

The Corps' continued interest in this project is sincerely appreciated. Please contact me with any questions.

Sincerely,

Bill Stockton

Wm. R. Stockton, P.E.,
Director

TRANSPORTATION AND PUBLIC WORKS DEPARTMENT

WRS:PH:dov

STATEMENT OF FINANCIAL CAPABILITY
WORKSHEET FOR PROJECT SPONSOR

DEBT HISTORY

A. BOND RATINGS	Rating	Date
General Obligation	AA	Sept '89
Revenue Bonds	A	July '89

B. DEBT	Outstanding	Project	Total
General Obligation Bonds	449,738,455	NA	449,738,455
Revenue Bonds	98,240,000	NA	98,240,000
Gross Direct Debt	546,978,455	NA	546,978,455
Direct Net Debt	540,369,399	NA	540,369,399
Overlapping Net Debt 1/	395,835,164	NA	395,835,164
Overall Net Debt			936,204,563
Other Debt 2/	NA		NA
Estimated Future Debt			NA

C. DEBT REPAYMENT SCHEDULE	(principal only) Outstanding	Project	Total
Year 1	64,241.902	NA	64,241,902
Year 2	63,681,486	NA	63,681,486
Year 3	62,473,454	NA	62,473,454
Year 4	61,044,799	NA	61,044,799
Year 5	59,771,286	NA	59,771,286
Direct Net Due in 5 Years			311,212,927

D. DEBT LIMITS

Cite legal authority for local sponsor to assume debt. Authorized by State law.
Describe any limits that apply.

Voter Authorization required by City Charter.

What percentage of this limit will be used?

Amount issued determined by Council.

FINANCIAL CONDITION	1987	1988	1989	Projected
Property Taxes	91,786,519	108,926,060	99,739,429	102,811,626
Other Revenues	75,232,707	79,965,052	86,720,589	93,911,496
Total Revenues	167,019,226	188,891,112	186,460,018	196,723,122
EXPENDITURES				
Operating Expenditures	188,885,510	198,676,512	207,385,767	203,926,722
Debt Service Payments	51,010,018	54,899,343	56,409,352	54,563,139
Total Expenditures	239,895,528	253,575,855	263,795,119	258,489,861
Expected Future Debt	NA	NA	NA	NA
REAL PROPERTY TAXES				
Real Property Tax Collection Rate	96.08	96.23	98.9 (est)	99 (proj)
Assessed Value of Real Property	23,453,566,705	21,289,060,006	17,699,987,321	16,761,869,249
Current Assessment Ratio	100 %	100 %	100 %	100 %
Full Market Value of Real Property	AV	AV	AV	AV

ECONOMIC FACTORS

Population

1970 Census	253,539
1980 Census	345,496
Current	479,000

Annual Rate of Change

4.5 % Increase

Personal Income

12,411,563,000

Per Capital Personal Income

25,911

Average Household Income

23,800

Average Unemployment Rate

1988 = 6.1 %

1/ Overlapping net debt is the sponsor's share of taxes owed to other taxing bodies within the community, ie., a flood district.

2/ Other debt obligations include outstanding leases, unfunded pension liabilities, and notes with a maturity greater than one year.

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

REPLY TO
ATTENTION OF:

June 25, 1990

Planning Division

LOCAL FLOOD PROTECTION PROJECT
SHOAL CREEK
AUSTIN, TEXAS

PUBLIC NOTICE

Interested parties are hereby notified that the District Engineer, Fort Worth District, proposes flood control improvements along Shoal Creek in Austin, Texas. A public meeting will be held on Wednesday, July 18, 1990, at 7:00 p.m. at the Murchison Community School, 3700 North Hills Drive, Austin, Texas.

Statutory Authority. This public notice is being issued to all interested parties in accordance with the provisions of Public Law 91-190, The National Environmental Policy Act of 1969. Authority for the proposed action is contained in the Flood Control Act of 1936, Section 6; Committee on Commerce Resolution of 1936; River and Harbor Act of 1937, Section 4; and River and Harbor Act of 1945, Section 6.

History and Purpose. By letter dated July 1981, the Mayor of Austin requested that the Fort Worth District, U.S. Army Corps of Engineers, investigate flooding problems along Shoal Creek and recommend potential solutions. Under authority of Section 205 of the Flood Control Act of 1948, a reconnaissance study was made which showed that enough damageable property existed in the flood plain to warrant more detailed studies to determine the Federal interest for construction of a flood control project. Results of the reconnaissance study were forwarded to higher Corps offices for review and, subsequently, a detailed project study was initiated under the specific authorization for Colorado River and Tributaries under the Flood Control Act of 1936 and subsequent acts. This public notice presents the results of detailed studies and provides the recommendations of the Fort Worth District for public review and comment.

Proposed Action. Initially, several basic structural and nonstructural measures were studied. Structural measures included detention reservoirs, channel improvements, levees, and tunnels. Basic nonstructural measures included flood proofing, zoning, permanent evacuation, and flood warning. After the initial analysis, seven alternatives were investigated in detail. The seven alternatives included a 'no action' plan, three channel plans, and three channel-tunnel combination plans. The "no action" alternative simply pertains to the probable future condition of the study area in the absence of a structural or nonstructural plan to reduce damages.

Channels in combination with tunnels were found to be more feasible than comprehensive channel plans. A total of six combination plans were investigated.

In a previous public notice dated June 23, 1987, and at a public meeting held on August 12, 1987, the Corps recommended a preliminary channel-tunnel combination plan that had two outfalls on Lake Austin, but was later revised because of public concern over potential impact of the outfall location on water quality, lakeside residences, and aesthetic and cultural points of interest. The revised plan consists of two smaller tunnels having different locations: one tunnel on Lake Austin away from the water intake facilities, and one on Town Lake.

The U.S. Army Corps of Engineers and the city of Austin, Texas, are proposing to implement flood control improvements along Shoal Creek within the city of Austin. The Recommended Plan for flood damage reduction consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek; a 40- to 50-foot bottom width, concrete-lined channel on Hancock Creek; and two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends approximately 400 feet downstream of Foster Lane. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall on Lake Austin near Bull Creek. The lower tunnel system consists of an intake on Shoal Creek in Pease Park near 19th Street; an outfall just east of Pressler Avenue with a stilling basin in a small ditch-like tributary just south of the Missouri Pacific Railroad tracks southwest of Orchard Road; and a 60-foot bottom width, grass-lined channel linking the stilling basin with Town Lake. Both tunnel intakes will include diversion structures which would be designed to allow low flows to pass through conduits downstream in the natural stream channel. The tunnel outfalls will include stilling basins which are designed to dissipate the energy of the water exiting the diversion tunnels. In addition, improvements on Hancock Creek include a concrete U-wall channel from Houston Street to Burnet Road; an attached box culvert under a shopping center; and a concrete channel continuing from the box culvert above Hancock Drive, transitioning to a grass-lined channel, and ending about 700 feet downstream of the drive.

The Recommended Plan also includes a linear recreation plan along the proposed channelized portion of Shoal Creek. The recreation plan includes a 1.4-mile trail for hiking, biking, and nature study, with park benches. Recreation average annual benefits are $77,000, and annual charges are $30,000 which includes $10,000 for operation, maintenance, and replacement. The recreational benefit-to-cost ratio is 2.6 to 1.0. The annual charges and annual benefits of the recreation are included in the cost for the Recommended Plan.

The Recommended Plan has a first cost of $82,272,000; a benefit-to-cost ratio of 1.4 to 1.0; an operation, maintenance, and replacement cost of

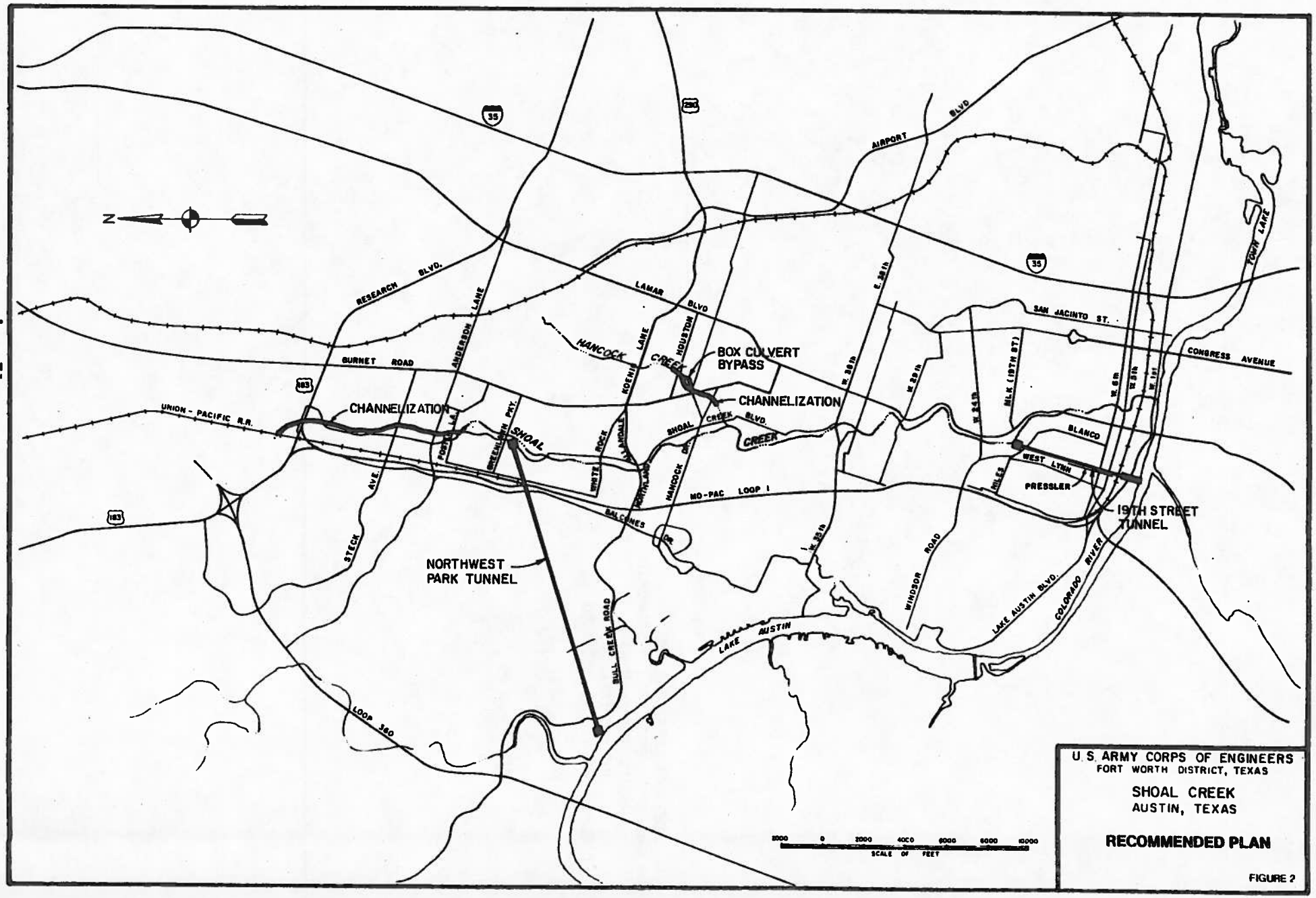
$39,000 annually; and average annual benefits of $11,974,000. The Recommended Plan is the National Economic Development plan. The attached project map depicts the Recommended Plan.

The environmental aspects of this project and its alternatives were considered in a preliminary Environmental Assessment prepared by the Fort Worth District. A preliminary Finding of No Significant Impact has been made which, pending receipt of public comments to the contrary, will be finalized at the end of the comment period. A preliminary Section 404(b)(1) evaluation has been completed and is attached as an exhibit to the preliminary Environmental Assessment. The report is being provided to appropriate agencies for review and comment. Copies have also been furnished to the Austin Central Library, 800 Guadalupe Street, and the North Loop Library, 2210 Hancock Drive, Austin, Texas. Copies of the Environmental Assessment are available from the Fort Worth District, Planning Division, ATTN: CESWF-PL-R, P.O. Box 17300, Fort Worth, Texas 76102-0300, upon request.

Any comments on the proposed action should be received no later than 30 days from the date of this notice. If no comments significantly affecting the decision are received by that date, it will be considered that there are no overriding objections. For further information, contact Miss Janis Cullum, Planning Division, Fort Worth District, at (817) 334-3876.

William D. Brown
Colonel, Corps of Engineers
District Engineer

Enclosure



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

SHOAL CREEK
AUSTIN, TEXAS

RECOMMENDED PLAN

FIGURE 2

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

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

CESWF-PL-P (c)

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

REPLY TO
ATTENTION OF:

June 25, 1990

Planning Division

Interested Agencies, Officials, Public Groups, and Individuals:

The U.S. Army Corps of Engineers and the city of Austin, Texas, are proposing to implement flood control improvements along Shoal Creek within the city of Austin. The Recommended Plan for flood damage reduction consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek; a 40- to 50-foot bottom width, concrete-lined channel on Hancock Creek; and two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends approximately 400 feet downstream of Foster Lane. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall on Lake Austin near Bull Creek. The lower tunnel system consists of an intake on Shoal Creek in Pease Park near 19th Street; an outfall just east of Pressler Avenue with a stilling basin in a small ditch-like tributary just south of the Missouri Pacific Railroad tracks southwest of Orchard Road; and a 60-foot bottom width, grass-lined channel linking the stilling basin with Town Lake. Both tunnel intakes will include diversion structures which would be designed to allow low flows to pass through conduits downstream in the natural stream channel. The tunnel outfalls will include stilling basins which are designed to dissipate the energy of the water exiting the diversion tunnels. In addition, improvements on Hancock Creek include a concrete U-wall channel from Houston Street to Burnet Road; an attached box culvert under a shopping center; and a concrete channel continuing from the box culvert above Hancock Drive, transitioning to a grass-lined channel, and ending about 700 feet downstream of the drive. The Recommended Plan also includes a linear recreation plan along the proposed channelized portion of Shoal Creek. The recreation plan includes a 1.4-mile trail for hiking, biking, and nature study, with park benches.

The enclosed Draft Interim Report, which includes an Environmental Assessment, has been prepared to document studies that recommend construction of the project. Included in the report is a Draft Finding of No Significant Impact (FONSI) that is proposed for the project.

The Draft Interim Report is being submitted for coordination with Federal, State, and local agencies having jurisdiction by law or expertise, and with groups, organizations, and individuals known to have an interest in the project.

Comments on the proposed action will be considered by the Corps of Engineers and the city of Austin in the decision making process. Final recommendations will be made in accordance with the National Environmental

40
A 73
YEARS

Policy Act procedures. Written comments should be submitted to the Fort Worth District at the following address within 30 days of the date of this notice.

U.S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
P.O. Box 17300
Fort Worth, Texas 76102-0300

Telephone: (817) 334-3876

To afford the public and other interested parties an additional forum for comment on the proposed action, a public meeting will be held on Wednesday, July 18, 1990, at 7:00 p.m. at the Murchison Community School, 3700 North Hills Drive, Austin, Texas.

Sincerely,

William D. Brown
Colonel, Corps of Engineers
District Engineer

Enclosure

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

REPLY TO
ATTENTION OF:

June 25, 1990

Planning Division

Interested (TRACS) Agencies:

The U.S. Army Corps of Engineers and the city of Austin, Texas, are proposing to implement flood control improvements along Shoal Creek within the city of Austin. The Recommended Plan for flood damage reduction consists of an improved 35- to 50-foot bottom width, grass-lined channel in the upstream portion of Shoal Creek; a 40- to 50-foot bottom width, concrete-lined channel on Hancock Creek; and two separate 14-foot diameter tunnel systems in the upper and lower reaches of the stream. The improved channel begins north of US Highway 183 at the MOPAC railroad bridge and ends approximately 400 feet downstream of Foster Lane. Two 11-foot diameter conduits allow water passage under US Highway 183. The upper tunnel system consists of an intake at the northern end of Northwest Park and an outfall on Lake Austin near Bull Creek. The lower tunnel system consists of an intake on Shoal Creek in Pease Park near 19th Street; an outfall just east of Pressler Avenue with a stilling basin in a small ditch-like tributary just south of the Missouri Pacific Railroad tracks southwest of Orchard Road; and a 60-foot bottom width, grass-lined channel linking the stilling basin with Town Lake. Both tunnel intakes will include diversion structures which would be designed to allow low flows to pass through conduits downstream in the natural stream channel. The tunnel outfalls will include stilling basins which are designed to dissipate the energy of the water exiting the diversion tunnels. In addition, improvements on Hancock Creek include a concrete U-wall channel from Houston Street to Burnet Road; an attached box culvert under a shopping center; and a concrete channel continuing from the box culvert above Hancock Drive, transitioning to a grass-lined channel, and ending about 700 feet downstream of the drive. The Recommended Plan also includes a linear recreation plan along the proposed channelized portion of Shoal Creek. The recreation plan includes a 1.4-mile trail for hiking, biking, and nature study, with park benches.

The enclosed report, which includes an Environmental Assessment, has been prepared to document studies that recommend construction of the project. Included in the report is a Draft Finding Of No Significant Impact (FONSI) that is proposed for the project.

The Draft Interim Report is being submitted for coordination with Federal, State, and local agencies having jurisdiction by law or expertise, and with groups, organizations, and individuals known to have an interest in the project.

Comments on the proposed action will be considered by the Corps of Engineers and the city of Austin in the decision making process. Final recommendations will be made in accordance with the National Environmental

Policy Act procedures. Written comments should be submitted to Mr. Tom Adams, State Single Point of Contact for the Texas Review and Comment System (TRACS), at the following address within 24 days of the date of this notice.

Mr. Tom Adams
State Single Point of Contact, TRACS
Governor's Budget and Planning Office
P.O. Box 12428
Austin, Texas 78711

The Governor's Budget and Planning Office has assigned the Shoal Creek report with the following State TRACS number for your use:

TX-R-90-06-14-0015-50-00

To afford the public and other interested parties an additional forum for comment on the proposed action, a public meeting will be held on Wednesday, July 18, 1990, at 7:00 p.m. at the Murchison Community School, 3700 North Hills Drive, Austin, Texas.

Sincerely,

William D. Brown
Colonel, Corps of Engineers
District Engineer

Enclosure

TEXAS REVIEW AND COMMENT SYSTEM

REVIEW NOTIFICATION

Applicant/Originating Agency: U.S. Army Corps of Engineers

Project Title: SHOAL CREEK FLOOD CONTROL

SAI/EIS#: TX-R-90-06-14-0015-50-00

Date Received: June 18, 1990 Date Comments Due BPO: 07/07/90

========== REVIEW PARTICIPANTS ==========

Texas Air Control Board
Bureau of Economic Geology
General Land Office
Texas Department of Health
Texas Historical Commission
State Dept. of Highways and Public Transportation
Texas Parks and Wildlife Department
Railroad Commission of Texas
State Soil and Water Conservation Board
Texas Water Commission
Texas Water Development Board
Capital Area Planning Council

Special Notes/Comments: Subject application will be provided to reviewer listed above directly by the Corps of Engineers.

[] No Comment. _____
Review Agency Signature

Return Comments to: _____
T. C. Adams, State Single Point of Contact
Governor's Office of Budget and Planning
P.O. Box 12428
Austin, Texas 78711
(512) 463-1778

Federal Emergency Management Agency

Region VI, Federal Center, 800 North Loop 288
Denton, Texas 76201-3698

NTH

July 3, 1990

U. S. Army Corps of Engineers
ATTN: CESWF-PL-P
P.O. Box 17300
Fort Worth, TX 76102-0300

Dear Sir:

Thank you for the opportunity to review and comment on the Draft Interim Report and Environmental Assessment for the Shoal Creek Project in Austin, Texas.

If you have not already done so, you are encouraged to obtain comments from the community's local floodplain management administrator:

Mr. Ray Windsor
Floodplain Administrator
505 Barton Springs Road
Austin, TX 78701

(512) 499-7109

If the ultimate alteration of the designated flood hazard area is significant, the community may wish to develop and submit a request for a Letter of Map Revision (LOMR) to this office. This request, if found justifiable, would result in the modification of the community's flood boundaries as designated by the Federal Emergency Management Agency for purposes of the National Flood Insurance Program.

If you have any further questions, please feel free to call me at (817) 898-9143.

Sincerely,

Bill Kuno
for Gregory W. Solovey
Natural Hazards
Program Specialist

40 YEARS 1950-1990
US Army Corps of Engineers
Fort Worth District

News Release

CESWF-PA-90-33 Sally Werst
Release No. Contact:
Immediate 11 July 90 817-334-3409
For Release: Phone:

SHOAL CREEK PUBLIC MEETING TO BE HELD

The U.S. Army Corps of Engineers, Fort Worth District, will hold a public meeting on the proposed flood control improvements for Shoal Creek on July 18, 1990. The meeting will begin at 7 p.m. at the Murchison Community School, 3700 North Hills Drive, Austin.

The recommended plan for flood damage reduction consists an upper and lower tunnel system, and channelization on both Shoal and Hancock Creeks. The intake of the upper tunnel would be at the northern end of Northwest Park, with its outfall on Lake Austin near Bull Creek. The intake of the lower tunnel would be located on Shoal Creek in Pease Park near 19th Street, with its outfall just east of Pressler Avenue. A stilling basin, just south of the Missouri-Pacific Railroad tracks, southwest of Orchard Road, would link a 60-foot bottom width, grass-lined channel with Town Lake. Both tunnel intakes would include diversion structures which would allow low flows in the creek to pass downstream in the natural stream channel.

The channelization on Shoal Creek would extend from the downstream side of the Missouri-Pacific Railroad Bridge to just downstream of Foster Lane. The channel would have

-MORE-

a 35-to 50-foot bottom-width. The channelization on Hancock Creek would include a 40- to 50-foot bottom-width concrete channel from just upstream of Houston Street to 700 feet downstream of Hancock Drive.

The proposed project also includes a recreation plan along the channelized portion of Shoal Creek which would include a 1.4-mile trail for hiking, biking and nature study, with park benches.

Copies of the preliminary Environmental Assessment are available at the Austin Central Library, 800 Guadalupe Street, and the North Loop Library, 2210 Hancock Drive.

For more information, call Janis Cullum, of the Fort Worth District's Planning Division, at (817) 334-3876.

-30-

CONVERSATION RECORD

TIME:

DATE: 7/13/90

TYPE: ☐ VISIT ☐ CONFERENCE ☒ TELEPHONE ☒ INCOMING ☐ OUTGOING

Location of Visit/Conference:

ROUTING

NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU	ORGANIZATION (Office, dept., bureau, etc.)	TELEPHONE NO:
Kolleen Wilwerding	LCRA	512-473 3200 x 2246

SUBJECT: Shoal Creek, Austin, Texas

SUMMARY: Ms. Wilwerding is reviewing the Shoal Creek report and indicated that they would be providing comments on that report. They have been working with the city of Austin to develop some water quality enhancement procedures. They have some concerns about the Shoal Creek Northwest Park Tunnel. They would like to work with us on possibly developing some water quality mitigation control. I suggested she read all the water quality information in the report and speak with our environmental planner

ACTION REQUIRED: Bob Shelton should call her next week

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Janis R. Cullum	Janis R. Cullum	7/13/90

ACTION TAKEN

SIGNATURE	TITLE	DATE

50271-101 ☆ GPO : 1988 O - 206-653 CONVERSATION RECORD OPTIONAL FORM 271 (12-76) DEPARTMENT OF DEFENSE

CONVERSATION RECORD

TIME:

DATE: 7/12/90

TYPE: ☐ VISIT ☐ CONFERENCE ☐ TELEPHONE ☒ INCOMING ☐ OUTGOING

Location of Visit/Conference:

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU: Bruce Long

ORGANIZATION (Office, dept., bureau, etc.):

TELEPHONE NO:

ROUTING

NAME/SYMBOL	INT

SUBJECT: Shoal Creek

SUMMARY: Mr. Long works with a management company which has a condimium development on the corner of Shoal Creek and Foster Lane. It sits right on the creek. He wanted to know what effect the channelization and hike & bike trail would have on his property. I told him that details had not been worked out, but minimal land would be involved in the channelization and the trail was an option for the city to decide upon. If the city wants the trail - it could go on either side of the channel. It would

ACTION REQUIRED

none

NAME OF PERSON DOCUMENTING CONVERSATION	SIGNATURE	DATE
Janis R. Cullum	Janis R. Cullum	7/12/90

ACTION TAKEN

SIGNATURE	TITLE	DATE

50271-101 ☆ GPO : 1988 O - 206-653 CONVERSATION RECORD OPTIONAL FORM 271 (12-76) DEPARTMENT OF DEFENSE

be 8 feet wide. If any lands needed to be purchased, the City would acquire the necessary easement for that. He wanted to be assured that his concern for the possible trail along the creek was known. I suggest he please his written comments on that so it would be on record.

STATE OF TEXAS
OFFICE OF THE GOVERNOR
AUSTIN, TEXAS 78711

WILLIAM P. CLEMENTS, JR.
GOVERNOR

July 27, 1990

Ms. Janis Cullum CESWF-PL-P
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

RE: TX-R-90-06-14-0015-50
Shoal Creek Flood Control

Dear Ms. Cullum:

Attached are subsequent comments received on the above captioned proposal.

If we can be of further assistance, please let me know.

Sincerely,

T. C. Adams
State Single Point of Contact

TCA/pon

Enclosure

POST OFFICE BOX 12428 • AUSTIN, TEXAS 78711 • 512/463-2000

TEXAS WATER DEVELOPMENT BOARD

Walter W. Cardwell, III, Chairman
Stuart S. Coleman, Vice Chairman
Glen E. Roney, Member

G. E. (Sonny) Kretzschmar
Executive Administrator

Thomas M. Dunning, Member
Charles W. Jenness, Member
Wesley E. Pittman, Member

July 23, 1990

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JUL 24 1990
GOVERNOR'S BUDGET OFFICE

6-14-15

Mr. Tom Adams
State Single Point of Contact
Governor's Office of Budget
and Planning
P. O. Box 12428
Austin, Texas 78711

Dear Mr. Adams:

Re: TRACS Review/Shoal Creek Flood Control Project

Board staff have reviewed the Draft Interim Report and Environmental Assessment for the proposed Shoal Creek flood control project in Austin, Texas by the Fort Worth District, U.S. Army Corps of Engineers. The recommended plan has been revised from an earlier plan to now divert water to Lake Austin only when Shoal Creek flows exceed 1,000 cfs. As a result, spills to Lake Austin are expected to occur only 1 or 2 times a year, as opposed to 9 or 10 times under the previous plan; therefore, the revised diversion plan will have less impact on the Lake Austin community and its water quality.

In conjunction with the Corps' proposed plan of structural improvements, the City of Austin and floodplain residents can also further abate future flood damages by continued enforcement of zoning regulations, participation in the National Flood Insurance Program, individual flood-proofing of structures where affordable, and responding to flood warnings generated by the alert system already installed in the Shoal Creek watershed.

As a result of revisions to the plans, an acceptable balance has been achieved between environmental impacts and flood protection. Thank you for the opportunity to comment on this needed flood control project.

Sincerely,

G. E. Kretzschmar
Executive Administrator

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GOVERNOR'S BUDGET OFFICE

COMMISSION
ROBERT H. DEDMAN, CHAIRMAN
RAY STOKER, JR.
WAYNE B. DUDDLESTEN

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
P.O. DRAWER 15426
AUSTIN, TEXAS 78761-5426
(512) 836-8640

ENGINEER-DIRECTOR
ARNOLD W. OLIVER, P.E.

July 18, 1990

CONTACT:

Contract No. 14545P5001
Project F 1124(25)
Control 3136-01-039
Travis County
Loop 1: From Steck Avenue To U.S. 183

Mr. Tom Adams
State Single Point of
Contact, TRACS
Governor's Budget and Planning Office
P. O. Box 12428
Austin, Texas 78711

RE: TX-R-90-06-14-0015-50-00

Dear Sir:

The Austin District office has reviewed the Environmental Assessment for the Shoal Creek flood control project proposed by the U. S. Army Corps of Engineers.

We recommend that the Corps of Engineers coordinate more closely with the City of Austin engineering staff regarding the proposed 11-foot diameter conduits at U.S. 183. The existing 3-9'x5' box culvert at this location functions as an outlet structure for a detention area immediately north of the highway right of way. Furthermore, this detention area is part of a system of detention facilities designed by the City of Austin and located upstream of U.S. 183. It is our understanding that the City of Austin staff intends to raise this issue at the public meeting this evening.

Because of its depth, the Northwest Park Tunnel as proposed will not conflict with any SDHPT facilities.

We appreciate the opportunity to comment on this important project.

Sincerely,

Roland E. Gamble, P.E.
District Planning Engineer

REG:GLL:ljb
cc: D-5
D-8E

STATE OF TEXAS
OFFICE OF THE GOVERNOR
AUSTIN, TEXAS 78711

WILLIAM P. CLEMENTS, JR.
GOVERNOR

July 19, 1990

Janis Cullum CESWF-PL-P
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, TExas 76102-0300

RE: TX-R-90-06-14-0015-50-00 / SHOAL CREEK FLOOD CONTROL

Dear Applicant:

Your environmental impact statement for the project referenced above has been reviewed. The comments received are summarized below and are attached.

The State Department of Highways and Public Transportation recommended the Corps coordinate more closely with the City of Austin engineering staff regarding the proposed 11-foot diameter conduits at U.S. 183 which is part of a detention system located upstream of U.S. 183. The Texas Water Commission recommended proper soil erosion and sediment control measures be implemented to prevent excessive transport of disturbed soil and construction debris from tunneling activities during stormwater runoff events. TWC also recommended all hazardous materials used by construction crews and fuels and lubricants be stored and handled properly to prevent accidental contamination of Shoal Creek, Town Lake, Lake Austin and ground water in the area.

We appreciate the opportunity afforded to review this document. Please let me know if we can be of further assistance.

Sincerely,

T. C. Adams, State Single Point of Contact

TCA//pon

Enclosures

POST OFFICE BOX 12428 • AUSTIN, TEXAS 78711 • 512 463-2000

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JUL 13 1990
GOVERNOR'S BUDGET OFFICE

TEXAS WATER COMMISSION

B. J. Wynne, III, Chairman
John E. Birdwell, Commissioner
Cliff Johnson, Commissioner

John J. Vay, General Counsel
Michael E. Field, Chief Hearings Examiner
Brenda W. Foster, Chief Clerk

Allen Beinke, Executive Director

July 12, 1990

Mr. T.C. Adams
State Single Point of Contact
Governor's Office of Budget and Planning
P.O. Box 12428, Capitol Station
Austin, Texas 78711-2428

Re: Draft Environmental Assessment (EA) and Interim Report for the Proposed U.S. Army Corps of Engineers Flood Control Project on Shoal Creek, Austin, Texas; TX-R-90-06-14-0015-50-00

Dear Mr. Adams:

The staff of the Texas Water Commission (TWC) has reviewed the referenced EA regarding the proposed flood control improvements along Shoal Creek in Austin, Texas.

We do not envision any major water quality impact associated with the completed project, however, there could be significant contamination during the construction phase. Since the project will require extensive soil disturbance during channelization of the Shoal Creek and Hancock Creek stream beds and during the tunneling process, adequate soil erosion and sediment control measures should be designed and implemented to prevent excessive transport of disturbed soil and construction debris during stormwater runoff events.

Surface water discharges from Shoal Creek and both tunnels enter the City of Austin's water supply reservoirs. All hazardous materials used by construction crews and fuels and lubricants required by heavy equipment should be stored and handled properly to prevent accidental contamination of Shoal Creek, Town Lake, Lake Austin and ground water in the area.

If you have any questions regarding this matter, please contact Mr. David Meesey of my staff at (512) 463-8443.

Sincerely,

Allen Beinke

Allen Beinke
Executive Director

Enclosure

P. O. Box 13087 Capitol Station • 1700 North Congress Ave. • Austin, Texas 78711-3087 • Area Code 512/463-7830

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JUL 11 1990
GOVERNOR'S BUDGET OFFICE

Texas General Land Office

Sally S. Davenport
Director
Coastal Division

Garry Mauro
Commissioner

July 3, 1990

Mr. Tom Adams
State Single Point of
Contact, TRACS
Governer's Office of
Budget and Planning
P.O. Box 12428
Austin, Texas 78711-2428

Dear Mr. Adams:

I have reviewed the proposed Shoal Creek Flood Control Draft Report and have found it to be thorough in conception and preparation. The project does not involve state-owned lands, however, and therefore is not within the jurisdiction of the Texas General Land Office.

I appreciate your consideration in including the General Land Office in this issue. Please contact me if I can be of further assistance.

Sincerely,

Sally S. Davenport

Sally Davenport
Director
Resource Management

SSD/km

Stephen F. Austin Building
1700 N. Congress Avenue
Austin, Texas 78701
(512) 463-5059

TEXAS STATE SOIL AND WATER CONSERVATION BOARD

311 North 5th
P.O. Box 658
Temple, Texas 76503
(817) 773-2250

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JUL 09 1990
GOVERNOR'S BUDGET OFFICE

July 5, 1990

T. C. Adams, State Single Point of Contact
Governor's Office of Budget and Planning
P.O. Box 12428
Austin, Texas 78711

Dear Mr. Adams:

We have reviewed the "draft interim report and environmental assessment of the Recommended Plan for Shoal Creek, Austin, Texas (TRACS #: TX-R-90-06-14-0015-50-00) prepared by the U.S. Army Corps of Engineers. We have no comment at this time.

We appreciate the opportunity to review this document.

Sincerely,

James M. Moore

James M. Moore, P.E.
Engineer

vd

STATE OF TEXAS
OFFICE OF THE GOVERNOR
AUSTIN, TEXAS 78711

WILLIAM P. CLEMENTS, JR.
GOVERNOR

August 4, 1990

Ms. Janis Cullum CESWF-PL-P
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

RE: TX-R-90-06-14-0015-50
Shoal Creek Flood Control

Dear Ms. Cullum:

Attached are subsequent comments received on the above captioned proposal.

If we can be of further assistance, please let me know.

Sincerely,

T. C. Adams
State Single Point of Contact

TCA/pon

Enclosure

POST OFFICE BOX 12428 • AUSTIN, TEXAS 78711 • 512/463-2000

THE STATE OF TEXAS

CURTIS TUNNELL
EXECUTIVE DIRECTOR

RECEIVED
AUG 0 1 1990
GOVERNOR'S BUDGET OFFICE

TEXAS HISTORICAL COMMISSION

P.O. BOX 12276 AUSTIN, TEXAS 78711 (512)463-6100

July 24, 1990

Mr. Tom Adams
State Single Point of Contact, TRACS
Governor's Budget and Planning Office
P.O. Box 12428
Austin, Texas 78711

Re: TX-R-90-06-14-0015--50-00, Draft Interim Report and Assessment, Shoal Creek, Austin, Travis County, Texas (COE-FWD, A5, B4, B7, B8)

Dear Sir:

Thank you for the opportunity to review the above referenced report. We agree with the Corps special concerns about the cultural resources listed on pages B-7 and B-8 of the report. These properties are the Seiders Oaks, Seiders Springs, Franz Fiset Dam, 41TV1293, and Pease Park. In addition we would note the existence of historic bridges across Shoal Creek between 29th and 6th streets. If these sites cannot be avoided by project impacts, then additional investigations will be needed.

We also concur with the Corps assessment of remaining objectives described on pages B-8 and B-9. In particular, the Bull Creek area at the Northwest Park Tunnel outlet should be surveyed as soon as possible. We are pleased to see that early attention has been given to survey of some potential areas where the spoil material generated from the tunnel excavations will be deposited. Consideration of cultural resources in such areas will be required even if sub-contracted out to be placed on private lands.

We will continue to review the project as the proposed undertaking's area of effect is further refined. If we can be of further assistance, please contact Dan Prikryl of my staff at (512) 463-6096 or Bruce Jensen of the National Register Department at (512) 463-6094.

Sincerely,

James E. Bruseth, Ph.D.
Deputy State Historic Preservation Officer

DP/JB/lft

cc: Michael Mocek, COE-Ft. Worth
Bruce Jensen, THC-NR

The State Agency for Historic Preservation

J.J. PICKLE
10TH DISTRICT, TEXAS

WASHINGTON ADDRESS:
242 CANNON HOUSE OFFICE BUILDING
(202) 225-4865

AUSTIN ADDRESS:
763 FEDERAL BUILDING
AUSTIN, TX 78701
(512) 482-5921

Congress of the United States
House of Representatives
Washington, DC 20515

COMMITTEES:
WAYS AND MEANS
JOINT COMMITTEE ON TAXATION

WAYS AND MEANS SUBCOMMITTEES:
CHAIRMAN, OVERSIGHT
HEALTH

August 2, 1990

Colonel William Doug Brown
U. S. Army Corp of Engineers
Ft. Worth District
P. O. Box 17300
Ft. Worth, Texas 76102-0300

Dear Colonel Brown:

Thanks for sending me a copy about the public hearing on the Shoal Creek project. Paul also told me it was a good session, and I was encouraged by the City's positive attitude.

As consideration of this project moves forward, I will certainly stay in touch with you.

With warmest personal regards, I am

Sincerely,

J. J. PICKLE

JJP:bkh
cc: Paul Hilgers

THIS STATIONERY PRINTED ON PAPER MADE WITH RECYCLED FIBERS

CERTIFIED MANAGEMENT OF AUSTIN
3007 LONGHORN BLVD., SUITE #100 • AUSTIN, TX 78759
(512) 339-6962

July 13, 1990

Department of the Army
Ft. Worth District, Corps. of Engineers
ATTN: William D. Brown
P.O. Box 17300
Ft. Worth, TX 76102-0300

RE: Shoal Creek Flood Protection Project

Dear Mr. Brown:

This letter is to express concerns about the proposed channelization to Shoal Creek and the proposed hike and bike trail.

Tiffany Condominiums is an 88 unit complex which is bordered on the south by Foster Lane and on the east by Shoal Creek. Its easternmost building extends nearly the entire length of the property and contains 30 residential units, half of them on the ground floor. Between the east wall of this building and the west bank of Shoal Creek is a flat area which is enclosed by a wooden privacy fence along the entire length of the building, except for a small "corridor" extending to the building wall and providing unimpeded access to electric meters. The fenced-in area, which is no more than 8′ wide in most places, is further subdivided inside into common areas and three patios to individual residential units. All 15 of the ground floor units either have bedroom windows, sliding glass doors, or both, opening onto some part of the fenced-in area.

Any hike-and-bike trail which would be constructed atop the west bank would have to be located on the ground presently within Tiffany's fenced-in area. This would not only involve a taking of the patios from three units, but could be expected to cause serious noise and security problems for the residents living in all the ground floor units, and noise problems for the residents of the upstairs units as well. Also, two upstairs units have balconies which are presently supported by posts rising from the ground of the patios below. These posts would either remain as an obstruction to a hike-and-bike trail, or the balconies, which would overhang that trail, would be in danger of collapse, with whatever threat that implies for the safety of hikers and bikers.

Loss of the privacy fence, in addition to having negative security implications, would also cause many of the residents to have windows looking directly across the creek at the rather unsightly back side of a commercial building and its driveway on which are stored numerous dumpsters.

For these reasons, the Tiffany Condominium Owners Association is strongly opposed to any plans for constructing a hike-and-bike trail on the west bank of Shoal Creek, at least between Anderson and Foster Lanes.

The Tiffany Condominium Owners Association would also express the hope that in any flood-control work on the west bank of the creek behind the Tiffany property, it would be possible to spare the trees which are there presently, as they both provide welcome shade and obstruct the view of the building across the creek for residents of upstairs units.

Sincerely,

CERTIFIED MANAGEMENT OF AUSTIN
Managing Agent for Tiffany Condominium
Owners' Association

Bruce Long
Association Manager

BL/cal
cc: Janis Cullum
Assn. President

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

REPLY TO
ATTENTION OF:

August 16, 1990

Planning Division

Mr. Bruce Long
Association Manager
Certified Management of Austin
3007 Longhorn Boulevard, Suite 100
Austin, Texas 78759

Dear Mr. Long:

Thank you for your letter of July 13, 1990, which provided comments on the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed recreation development along the creek. The hike and bike trail is optional to the project. We also appreciate your concern for the trees along the creek and the structural integrity of the buildings. Our channel will be designed so as not to undermine the buildings in any way. As design of the channel progresses, details of that area will be developed and any trees located along the channel bank which can be avoided will be considered.

A copy of your comments on the proposed project will be forwarded to the city for their consideration. Please feel free to contact Miss Janis Cullum at 817/334-3876 if you have any questions.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

Mrs. Tom Long
5004 Balcones Drive
Austin, Texas 78731

18 July 1990

Col. William D. Brown, District Engineer
Ft. Worth Corps of Engineers
Post Office Box17300
Ft. Worth, Texas 76102-0300

Dear Col. Brown:

Thank you for your letter of June 25, with regard to the Flood Protection Project for Shoal Creek in Austin, Texas.

I am opposed to this project on several grounds:

1.) As plans presently stand, the runoff from Shoal Creek would be forced into the Colorado River at a point just above the intake of the existing Green Treatment Plant, which recently was renovated and updated for use for a 20-year period.

2.) The cost to taxpayers for this project would be enormous -- some $20 million, according to the best estimate --- and that does not include the cost of moving the Green Plant, which , of course, would be necessary if the project is undertaken.

3.) It is my understanding that only a superficial environmental impact analysis has been made. This needs to be done in depth.

Thank you again for your notice, and for the opportunity to stand up and be counted in this matter.

Sincerely,

Mrs. Tom Long

Mrs. Tom Long

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

REPLY TO
ATTENTION OF:

August 16, 1990

Planning Division

Mrs. Tom Long
5004 Balcones Drive
Austin, Texas 78731

Dear Mrs. Long:

Thank you for your letter of July 18, 1990, which provides comments on the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed project. Your comments will be considered in our final analysis of the proposed project and will be provided to the city for their consideration. If you need any additional information, please contact Miss Janis Cullum at 817/334-3876.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

July 18, 1990

To: U.S. Army Corps of Engineers; City of Austin; U.S. Rep. J. J. "Jake" Pickle

From: David M. McNeely, owner of house at 6408 Shoal Creek

Re: proposed plan by the Corps to divert Shoal Creek flood water through two 14-foot tunnels for $82 million

While I appreciate the fact that some action is proposed concerning the properties that can be flooded when Shoal Creek goes out of its banks, I think that the $82 million could be better spent to buy those that are flood-prone, tear them down, and make the land into parkland.

My property at 6408 Shoal Creek has flooded in 1981, 1982 and 1987. It has been rebuilt repeatedly with the aid of federal flood insurance. I do not think that the cost of buying properties such as mine, which is probably the most flood-prone house still existing on the creek, would cost $82 million. Also, the resulting parkland would be a better use for the creek bed than the flood-prone houses.

I will be happy to discuss this further with anyone at any time. Thanks very much for your attention.

David M. McNeely

David M. McNeely

P.O. Box 670
Austin, TX 78767

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

REPLY TO
ATTENTION OF:

August 16, 1990

Planning Division

Mr. David M. McNeely
P.O. Box 670
Austin, Texas 78767

Dear Mr. McNeely:

Thank you for your letter of July 18, 1990, concerning the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed project. Your comments will be considered in our final analysis of the proposed project and will be provided to the city for their consideration. If you need any additional information, please contact Miss Janis Cullum at 817/334-3876.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

Post Office Box 804
Austin, Texas 78767
July 19, 1990

U. S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Gentlemen:

This letter is my strong and urgent protest AGAINST the invasion of what is called the proposed Lower Tunnel of the Shoal Creek Flood Control Plan in Austin, Texas, especially the route now designated in displayed maps "just east of Pressler Avenue" [should be Street.]

The expected route "just east of Pressler" passes lengthwise apparently down the middle of some 670 feet of approximately two acres of property known locally as Flower Hill (the Smoot Family Estate) owned mostly by the Heritage Society of Austin and partly by myself. This property has long been identified as historic, even far back the recipient of official medallions from the Austin, State of Texas, and National Trust Registers. Under legal contract the Heritage Society of Austin has extensive and intensive plans, already on the way, to develop this property into a house museum/historic park asset of which the City of Austin and its visitors will be proud to exhibit as a souvenir of the past. The house on the property is 113 years old, the last of Austin's OLD homes still occupied by the original family; it is built of materials no longer available anywhere (antique hand-made brick and antique wood of a quality no longer found), therefore not replaceable at any cost.

Although the depth of the tunnel to the north of this property is described as being from thirty to one hundred feet below the surface, the location of Flower Hill is so close to the expected outlet at Town Lake that the tunnel would be much closer to the surface underneath this historic house and the rest of its property, therefore constituting a fearful danger of damage -- if not at once, surely in long years to come when concrete cracks, shifts, and otherwise deteriorates.

For the sake of the heritage values of Austin, PLEASE DO NOT LOCATE THIS TUNNEL UNDERNEATH OR EVEN NEAR FLOWER HILL, "JUST EAST OF PRESSLER."

With much appreciation for your understanding and for your changing this threatened tunnel away from the Pressler Street area,

Most sincerely,

Jane Smoot

(Miss) Jane Smoot

PL
PM
DE
XO

19 July 1990

Col. William D. Brown, District Engineer
Ft. Worth Corps of Engineers
P. O. Box 17300
Ft. Worth, TX 76102-0300j

Dear Col. Brown:

In re your letter of 25 June 1990 regarding the Shoal Creek destruction, I am totally opposed to it - even if I lived right ON the creek, I would be opposed - there are so few natural places left in this town; between engineers and developers, it seems that we are to have "improvements" (i.e., cement-covered everything) rammed down our throats regardless of whether we vote things down or not - money and power will out, no matter what "the voters" want. So here we go again, another project to cement up a creek, dig and cement tunnels, and put "trails" and benches, and make a "recreation" area out of what is now a lovely, unspoiled, natural place to walk and commune with nature. For what? We have floods BECAUSE there is too much cement, too much impervious cover everywhere - and now you want to put MORE cement to channel floods caused by building in the first place. It won't end until every single piece of dirt, and every single body of water is "regulated, improved and developed" right out of existence.

Don't do this only because you "can", and because engineers want more engineering projects for something to do, or because you don't give a damn about nature (it's just in the way of development, right?) or about what we out here WANT to have in our neighborhoods (what do we know, anyway, we're just dumb civilians, right?). Don't do it at all. We don't need more cement. There's too much of it already.

Constantly we vote down "development", and the developers go right ahead and start doing them anyway - just for the short-term gain (or for whatever power trip it gives them), and damn the consequences.

Well, not this time - not one of the very few areas left without TOO much damage (there has already been some cementing and "improving" near 2222, destroying the naturalness of part of the area - don't wreck the rest of it. Leave us some creeks and grass and trees, so we can at least PRETEND we live in a real earth-place, not in some futuristic glass and plastic bubble with no nature left at all.

Yes, I can hear it now: "Oh, another kook, throw it in the trash" - I'm just fed up with what passes for "improvements" - cement, cement, and more cement - parking lots, widened roads (so people can go even FASTER in our neighborhoods - they are now going around 55mph in residential areas), and now cemented creeks.

Forget it! Cement up Fort Worth or Dallas, or Houston, they are lost causes anyway.

Leave what's left of Austin alone! With no rains, plus the global warming (which the government doesn't see fit to acknowlede)("there's no danger to anyone"), what chance of flood anyway?

Sincerely,

M. R. Sutton
7201 Wood Hollow Dr. #281
Austin, TX 78731

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

REPLY TO
ATTENTION OF:

August 17, 1990

Planning Division

Mr. M. R. Sutton
7201 Wood Hollow Drive, #281
Austin, Texas 78731

Dear Mr. Sutton:

Thank you for your letter of July 19, 1990, which provides comments on the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed project. We would like to clarify one item. For the most part, the channelization along Shoal Creek will not be concrete. The side slopes will be grass-lined and the bottom will be the natural rock which exists in the area. There will be less than 300 feet of concrete along the channel beside Northwest Park. The tunnels will be concrete-lined.

Your comments will be considered in our final analysis of the proposed project and will be provided to the city for their consideration. Please feel free to contact Miss Janis Cullum at 817/334-3876 if you have any questions.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

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

REPLY TO
ATTENTION OF:

August 17, 1990

Planning Division

Miss Jane Smoot
P.O. Box 804
Austin, Texas 78767

Dear Miss Smoot:

Thank you for your letter of July 19, 1990, which provided comments on the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed project. They will be considered in our final analysis of the proposed project and will be forwarded to the city for their consideration. If you have any questions, please contact Miss Janis Cullum at 817/334-3876.

Sincerely,

T. R. Vogt
for Michael J. Macek, P.E.
Chief, Planning Division

OLD WEST AUSTIN NEIGHBORHOOD ASSOCIATION
1207 West 10th Street
Austin, Texas 78703

July 25, 1990

U.S. Army Corps of Engineers,
Fort Worth District
ATTN: CESWF-PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Re: Shoal Creek Flood Control Plan,
Austin, Texas

Dear Sir or Madam:

The proposed flood control plan includes a proposal for a tunnel running from Pease Park just east of Pressler Avenue into Town Lake.

If built, this tunnel would adversely impact what may be the most important historical site in our Neighborhood, namely the Smoot Home (also known as "Flower Hill"). This 113-year-old home has recently been purchased by the Austin Heritage Society, and is destined to become a museum.

Although this matter has not yet been formally discussed by our Neighborhood Association, I can assure you that this proposal is likely to generate a great deal of opposition.

Sincerely,

Philip C. Friday, Jr.
Chair, Steering Committee

PCF/sw

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

REPLY TO
ATTENTION OF:

August 16, 1990

Planning Division

Mr. Philip C. Friday, Jr.
Chair, Steering Committee
Old West Austin Neighborhood Association
1207 West 10th Street
Austin, Texas 78703

Dear Mr. Friday:

Thank you for your letter of July 25, 1990, which provided comments on the proposed Shoal Creek, Austin, Texas, project.

We appreciate your comments on the proposed project. Your comments will be considered in our final analysis of the proposed project and will be provided to the city for their consideration. If you need any additional information, please contact Miss Janis Cullum at 817/334-3876.

Sincerely,

for Jerry A. McCrory
Michael J. Mocek, P.E.
Chief, Planning Division

Lower Colorado River Authority

Post Office Box 220 Austin, Texas 78767 • (512) 473-3200

July 24, 1990

Col. William D. Brown
U.S. Army Corps of Engineers
Fort Worth District
Attn: CESWF - PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Dear Col. Brown:

The Lower Colorado River Authority (LCRA) has serious concerns regarding public safety associated with flooding in the Shoal Creek watershed. We applaud the Corp's efforts to minimize this problem. LCRA also is pleased with the efforts of your agency to avoid full channelization of Shoal Creek. As stewards of the Colorado River whose mandate is to protect and enhance the water resources of our basin, however, LCRA has serious concerns about the water quality impacts of the project as currently proposed.

LCRA's primary reservation with the current proposal is the diversion of polluted water from Shoal Creek at Northwest Park into Lake Austin, which is very clean and the primary drinking water source for the City of Austin. Shoal Creek is a highly urbanized watershed which carries significant pollutant loads (13,000 tons of total suspended solids, 19 tons of nitrogen and 10 tons of phosphorus) into Town Lake on an annual basis. Continued intensive development coupled with the increased traffic loadings associated with improvements to three major highways in the upper watershed assures increased degradation of the water quality in Shoal Creek in years to come, particularly above the proposed diversion into Lake Austin. Moving this pollution upstream into the Lake Austin watershed without providing extensive treatment is inconsistent with the City of Austin and LCRA's water quality protection programs which extend back for over a decade. The City and LCRA are continuing to pursue these programs in an interlocal agreement targeted at implementation and clean up measures for urban watersheds such as Shoal Creek.

Because of the huge pollutant loads that flow from Shoal Creek, municipal and recreational uses of Lake Austin may be significantly impacted by the diversion of Shoal Creek flows into Lake Austin. The accumulation of toxic materials in the sediments carried by runoff from urban areas such as Shoal Creek has resulted in chlordane levels exceeding established standards for human consumption in fish tissue

samples from Town Lake. Similar testing on Lake Austin shows no accumulation of toxics. LCRA's goal in cleaning up the Colorado River is to prevent pollution of the type we are currently experiencing in Town Lake. The problems of Town Lake are persistent and extremely difficult to remedy. Diversion of polluted runoff from Shoal Creek is not consistent with our goals of monitoring and enhancing water quality.

The proposed diversion could seriously impact the suitability of Lake Austin for contact recreation and thereby adversely affect Austin's economy. Lake Austin already exceeds the fecal coliform standard of 200 mg/l for contact recreation following significant rainfall events. The diversion of runoff from a watershed as heavily urbanized as Shoal Creek will compound that problem.

While the need to alleviate the flooding problems on Shoal Creek should not be minimized, the protection of our water resources is also critical. The LCRA is confident that alternatives exist which can reduce flooding without compromising water quality. Alternatives that warrant further examination include:

1) routing any upstream tunnel into Town Lake rather than Lake Austin and providing water quality enhancement ponds as an integral part of any tunnel outlet;

2) the use of a combination of flood control and water quality ponds in the upper reaches of the watershed to control peak flows and provide water quality mitigation; and

3) a longer term non-structural approach which would include removal of some structures from the floodplain, particularly for the more frequent storm events. Use of zoning controls to prohibit new development in the floodplain could reduce damages over time as existing structures outlived their usefulness.

We look forward to working with you and the City of Austin to find a mutually acceptable solution to this problem.

Sincerely,

Mark Rose
Deputy General Manager

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

REPLY TO
ATTENTION OF:

August 17, 1990

Planning Division

Mr. Mark Rose
Deputy General Manager
Lower Colorado River Authority
P.O. Box 220
Austin, Texas 78767

Dear Mr. Rose:

Thank you for your letter of July 24, 1990, which provided comments on the proposed Shoal Creek, Austin, Texas, project.

As you are aware, some of your staff met with representatives from the city and Corps of Engineers on August 6, 1990. We appreciate your staff arranging this meeting.

We understand your concerns and will be working closely with the city to develop recommendations for any modifications to the proposed project which involve water quality. We will involve your staff on any of these discussions.

We appreciate your comments on the project. Please feel free to contact Miss Janis Cullum at 1-800-722-8550 if you have any questions.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

July 24, 1990

Mr. Bob Shelton
Dept. of the Army
Fort Worth Dist. Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

Dear Mr. Shelton:

After attending the public meeting on 7/18/90 in Austin re: proposed flood control on Shoal Creek, I have many concerns about the proposal.

One question which relates to my property is: What changes will take place in the water level or amount of water flow behind my house. How high does the water have to be before it flows into the proposed tunnel at Northwest Park and therefore diminishes the flow behind my house.

I live at 4921 Strass Drive, approximately 10 houses north of the dam at West 49th Street. Much wildlife lives near the creek; the great blue heron, green heron, sunfish, turtles and yes, crawfish as long as 6-7 inches. My concern with the possible change in water level relates directly to the quality of wildlife habitat now existing in the greenbelt area behind my house.

I appreciate your time and effort to answer this letter and look forward to your reply.

Sincerely,

Mary C. Kaiser

Mary C. Kaiser
4921 Strass Drive
Austin, TX 78731

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

REPLY TO
ATTENTION OF:

August 17, 1990

Planning Division

Ms. Mary C. Kaiser
4921 Strass Drive
Austin, Texas 78731

Dear Ms. Kaiser:

Thank you for your letter of July 24, 1990, concerning the proposed Shoal Creek, Austin, Texas, project.

In response to your question on the change in flow in the creek behind your house, the following information is provided. Based on our analysis, normal flows in the creek should not change. Changes in the creek will occur only during floodflows on the creek. Even during floodflows, the diversion structure for the Northwest Park tunnel will allow 1,000 cubic feet per second of water to pass down Shoal Creek prior to diversion into the tunnel. Based on the description of the location of your house, we estimate that a 1-year flood event would be lowered by about one foot. A 100-year flood event would be lowered by about 0.5 feet.

These proposed changes to the flows on Shoal Creek are not expected to have a significant effect on the wildlife habitat located along the reach of creek behind your house.

We appreciate your comments on the proposed project. They will be provided to the city of Austin for their consideration. Please feel free to contact Miss Janis Cullum at 817/334-3876 if you have any questions.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

The Heritage Society of Austin, Inc.

POST OFFICE BOX 2113, AUSTIN, TEXAS 78768
OFFICES IN THE OLD DRISKILL HOTEL BUILDING, SIXTH AND BRAZOS STREETS
TELEPHONE 512/474-5198

July 24, 1990

U. S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
Post Office Box 17300
Fort Worth, Texas 76102-0300

Dear Sirs:

We were recently made aware of the proposed Shoal Creek Flood Control Project through the media. As property owners just east of Pressler Street, we were very surprised that we were not informed otherwise.

Our historic property just east of Pressler is known as Flower Hill and we have owned the property in a life tenancy agreement with Miss Jane Smoot since 1973. It is our intention to ultimately develop a historical museum on this site and have been working toward this goal for many years.

The property is a significant cultural asset to the City of Austin and it is our opinion that the flood control plan as presented would adversely affect our property.

This is to serve as notice that our organization is vehemently opposed to your proposal.

We certainly hope that in the future we will be informed in advance of any further actions with regard to your planning for the project or its status.

Sincerely yours,

Jane Hall

Jane Hall
President

cc: Lee Cooke, Mayor, City of Austin
Camille Barnett, City Manager

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

REPLY TO
ATTENTION OF:

August 17, 1990

Planning Division

Ms. Jane Hall
President
The Heritage Society of Austin, Inc.
P.O. Box 2113
Austin, Texas 78768

Dear Ms. Hall:

Thank you for your letter of July 24, 1990, which provided comments on the proposed Shoal Creek, Austin, Texas, project. We note that a copy of your letter has been sent to the city of Austin for their consideration.

Your name will be added to our mailing list. We appreciate your comments and should you have any questions, please feel free to contact Miss Janis Cullum at 817/334-3876.

Sincerely,

for T. R. Vogt
Michael J. Mocek, P.E.
Chief, Planning Division

August 1, 1990

Forth Worth District
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

Dear Madams and Sirs:

This letter is in reference to your report INTERIM REPORT AND ENVIRONMENTAL ASSESSMENT--SHOAL CREEK AUSTIN, TEXAS. Generally, I find the report quite well done. There is, however, one area of the report that I find hard to accept. This segment of the report concerns the estimation of the benefit to cost ratio.

The CORPS estimated the potential benefit at $13.9 million per year. This estimate is essentially the average annual saving from not having as much flood damage after the project. This estimate seems inordinately high. Consider the following information:

- The Austin-American Statesman quoted a $14 million loss during the May, 1981 Shoal Creek flood.
- Even with a reasonable inflation rate that would be less than $25 million in 1990 dollars.
- The CORPS considered the damage in the 1981 flood to be $30 million.
- The single occurrence flood for a 100-yr recurrence was estimated by the CORPS to cause $76.4 million and for a 50-yr recurrence to cause a $60.3 million loss.
- Since the 1981 flood was judged to be at least a 50-yr and more likely a 100-yr recurrence storm, the above estimates seem quite at odds with the experience.
- Moreover, the CORPS 1-yr damage estimate was $3.1 million which is totally inconsistent with the experience since I moved to Austin in 1985.
- Finally, the CORPS did not reduce their damage estimates by the insured losses--even through they did take credit for an insurance overhead reduction as a benefit.

I believe a reasonable estimate for the benefit (basically the flood loss without the project minus the flood loss with the project) would be more in the range of $5 to $7 million. Unfortunately, when combined with a cost of about $8.8 million annually (amortized over about 20 years at 8-7/8 % interest instead of the 100 years stated in the report), the benefit to cost ratio is less than one which means the project should not be undertaken. I firmly believe that is the RIGHT conclusions.

Sincerely,

Ronald B. Lantz

5917 Overlook Dr.
Austin, TX 78731

Advisory Council On Historic Preservation

The Old Post Office Building
1100 Pennsylvania Avenue, NW, #809
Washington, DC 20004

Reply to: 730 Simms Street, #401
Golden, Colorado 80401

August 8, 1990

U.S. Army Corps of Engineers
Fort Worth District
ATTN: CEWF-PL-P
P.O. Box 17300
Fort Worth, TX 76102-0300

REF: Shoal Creek, Austin, TX
Draft Interim Report and Environmental Assessment

Dear Sir:

We have reviewed the Draft Interim Report and Environmental Assessment for the Shoal Creek Flood Control Improvement Project which was circulated for Comment pursuant to the National Environmental Policy Act of 1969. Since it appears that the channelization of this creek has the potential to effect a number of historic properties, we encourage you to continue consultation under the procedures established by the Council's regulations, 36 CFR Part 800, as well as to follow the guidance contained in Appendix B of the Draft EA.

Thank you for the opportunity to review and comment on the Draft EA. If you have any questions, please contact Lee Keatinge of the Western Office of Project Review at (303) 236-2682 or FTS 776-2682.

Sincerely,

for Claudia Nissley
Director, Western Office
of Project Review

United States Department of the Interior

NATIONAL PARK SERVICE
SOUTHWEST REGION
P.O. BOX 728
SANTA FE, NEW MEXICO 87504-0728

IN REPLY REFER TO:

L7619(SWR-REC)

AUG 13 1990

Colonel William D. Brown
District Engineer
Fort Worth District
U.S. Army Corps of Engineers
Post Office Box 17300
Fort Worth, Texas 76102-0300

Dear Colonel Brown:

This responds to your request for our review of the draft interim report and environmental assessment for Shoal Creek, Austin, Travis County, Texas. The following comments are provided on a technical assistance basis.

The document provides a good discussion of recreation resources, opportunities, and impacts in the project area. The change in plans to include more tunnel construction than channelization represents a substantial reduction in impacts to recreation resources. In addition, we are pleased that an optional recreational plan has been developed which will provide a paved hike/bike trail.

The assessment addresses impacts of the 19th Street outlet/stilling basin on Deep Eddy Park. The document appropriately identifies Deep Eddy Park as having received a matching grant from the Land and Water Conservation Fund (L&WCF) and discusses the requirements of Section 6(f) of the L&WCF Act relating to conversion of use of recreation lands. Coordination and consultation concerning compliance with Section 6(f) of the L&WCF Act is ongoing and should be noted on page EA-5, "Relationship to Environmental Requirements."

The City of Austin has not yet selected an alternative for design of the 19th Street outlet/stilling basin in Deep Eddy Park, nor have they initiated the process for obtaining approval for a conversion of use of lands in Deep Eddy Park pursuant to Section 6(f). It appears that selection of the <u>optional</u> lagoon design in Deep Eddy Park would continue to allow for full utilization of the area for public outdoor recreation purposes and would constitute a change in <u>type</u> of recreation use rather than a conversion of use from recreation to flood control purposes. It may be possible to exempt this change in type of recreation use from the requirements of Section 6(f). However, a formal determination on Section 6(f) applicability and compliance remains to be be made.

We appreciate the opportunity to review this proposal.

Sincerely,

R B Smith

Associate Regional Director,
Resources Management,
Southwest Region

cc:
Mr. Steve Bozak
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744

Post Office Box 804
Austin, Texas 78767
August 13, 1990

Mr. Ron Ruffennach
U. S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Dear Mr. Ruffennach:

As you see from the attached enclosures, many of us in the affected areas -- groups and individuals -- strongly oppose the proposed Lower Tunnel of the Shoal Creek Flood Control Plan in Austin, Texas, especially the route designated in displayed maps (at the public meeting on July 18, 1990) "just east of Pressler Avenue "[should be Street.]

Please read carefully all of the attached letters detailing the danger to one of Austin's most valuable historic sites: Flower Hill, one of the last of the OLD homes, a treasure house 113 years old, now being developed as a house museum for all of Austin and Texas by the Heritage Society of Austin -- a gift of and from the Past that has been on the Austin, the Travis County, the State of Texas, and the National Register medallion lists for years.

YOUR TUNNEL PROPOSES TO RUN LENGTHWISE UNDERNEATH THIS ENTIRE PROPERTY (1316 West Sixth Street, on the corner of West Sixth and Pressler Street) AT A DEPTH OF ABOUT FIFTEEN FEET (quoting Col. William D. Brown to me at the public meeting on July 18.)

THIS ANTIQUE STRUCTURE BUILT OF HAND-MADE BRICK AND WOOD OF A QUALITY THAT IS IRREPLACEABLE, NOT TO MENTION ANTIQUE FURNISHINGS THAT GO BACK FIVE GENERATIONS, WILL BE AT SEVERE RISK FROM SUCH A TUNNEL BORED IN UNDERNEATH.

PLEASE STOP AND ABANDON ALL PLANS FOR THIS TUNNEL!

With much gratitude to you for conscientiously understanding this urgent appeal and therefore for ending such a planned tunnel,

Most sincerely,

Jane Smoot

(Miss) Jane Smoot
1316 West Sixth Street

cc: Mr. Tom Hegemier
Mr. Bill Stockton
both of
The City of Austin Public Works
Stormwater Management Division
505 Barton Springs Road
Austin, Texas 78704

Shoal Creek study could delay water diversion

By Debbie Hiott
American-Statesman Staff

An environmental impact study being considered by city officials could add a year's delay to a proposal to divert water from Shoal Creek into Austin lakes.

U.S. Army Corps of Engineers officials say such a study would require extra money and effort on the part of the corps.

"They're lengthy, and they're very involved," said Ron Ruffennach, spokesman for the Fort Worth District of the corps, which is planning the project for the city.

The project proposes that two 14-foot diameter tunnel systems be installed in the upper and lower parts of Shoal Creek, easing water levels in the stream during flooding.

One tunnel would take in excess water at the northern end of Northwest Park and drop it in Lake Austin near Bull Creek. The other tunnel would receive water at Pease Park near Martin Luther King Jr. Boulevard and flow to a basin east of Pressler Avenue. The basin will be connected to Town Lake by a 60-foot-wide grass-lined channel.

The Corps of Engineers has done an environmental assessment on the proposal, and concluded that the tunnels would have no significant impact on the environment because water diversion into Lake Austin and Town Lake would be too infrequent to contaminate the water.

"It would not be necessary to do an environmental impact study," Ruffennach said. "The environmental assessment has already been done and showed there was no problem."

However, city officials believe the proposed tunnels might be too close to the Davis and Green water treatment facilities, and that extra treatment would be required to keep out debris and contaminated water.

"That is the concern of Water and Wastewater that there might be additional costs incurred," said Tom Hegemier with the city's stormwater management division of the Public Works Department.

An environmental impact study is generally more extensive than an assessment, said Janis Cullum, a spokeswoman for the corps.

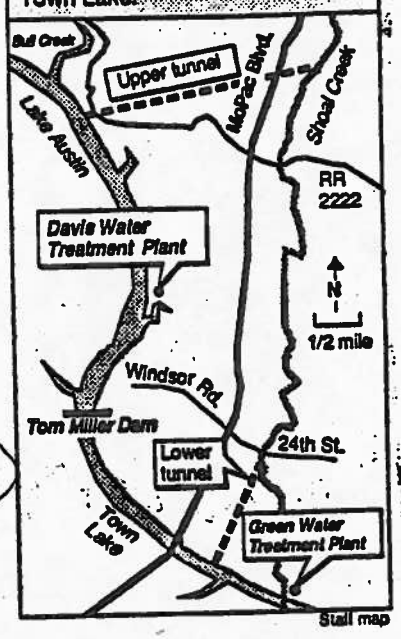
Bill Stockton, director of public works, said the city's stormwater management and environmental and conservation services departments have been discussing the possibility of requesting the study, but said he does not know when a decision will be made.

The City Council must first give approval to begin construction on the project, which is projected to cost the city $20 million. Corps officials would then petition Congress for authorization and appropriations, which would at least five years, corps officials said. Construction would take another five years, they said.

The corps' study of the Shoal Creek flooding problems was prompted by a May 1981 flood that killed 13 people. Five of the victims died in Shoal Creek.

Proposed Shoal Creek tunnel project

The U.S. Army Corps of Engineers has proposed building tunnels to divert floodwaters from Shoal Creek to Lake Austin and Town Lake.



Staff map

Post Office Box 804
Austin, Texas 78767
July 19, 1990

U. S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Gentlemen:

This letter is my strong and urgent protest AGAINST the invasion of what is called the proposed Lower Tunnel of the Shoal Creek Flood Control Plan in Austin, Texas, especially the route now designated in displayed maps "just east of Pressler Avenue" [should be Street.]*

The expected route "just east of Pressler" passes lengthwise apparently down the middle of some 670 feet of approximately two acres of property known locally as Flower Hill (the Smoot Family Estate) owned mostly by the Heritage Society of Austin and partly by myself. This property has long been identified as historic, even far back the recipient of official medallions from the Austin, State of Texas, and National Trust Registers. Under legal contract the Heritage Society of Austin has extensive and intensive plans, already on the way, to develop this property into a house museum/ historic park asset of which the City of Austin and its visitors will be proud to exhibit as a souvenir of the past. The house on the property is 113 years old, the last of Austin's OLD homes still occupied by the original family; it is built of materials no longer available anywhere (antique hand-made brick and antique wood of a quality no longer found), therefore not replaceable at any cost.

Although the depth of the tunnel to the north of this property is described as being from thirty to one hundred feet below the surface, the location of Flower Hill is so close to the expected outlet at Town Lake that the tunnel would be much closer to the surface underneath this historic house and the rest of its property, therefore constituting a fearful danger of damage -- if not at once, surely in long years to come when concrete cracks, shifts, and otherwise deteriorates.

For the sake of the heritage values of Austin, PLEASE DO NOT LOCATE THIS TUNNEL UNDERNEATH OR EVEN NEAR FLOWER HILL, "JUST EAST OF PRESSLER."

With much appreciation for your understanding and for your changing this threatened tunnel away from the Pressler Street area,

Most sincerely,

Jane Smoot

The Heritage Society of Austin, Inc.

POST OFFICE BOX 2113, AUSTIN, TEXAS 78768
OFFICES IN THE OLD DRISKILL HOTEL BUILDING, SIXTH AND BRAZOS STREETS
TELEPHONE 512/474-5198

July 24, 1990

U. S. Army Corps of Engineers, Fort Worth District
ATTN: CESWF-PL-P
Post Office Box 17300
Fort Worth, Texas 76102-0300

Dear Sirs:

We were recently made aware of the proposed Shoal Creek Flood Control Project through the media. As property owners just east of Pressler Street, we were very surprised that we were not informed otherwise.

Our historic property just east of Pressler is known as Flower Hill and we have owned the property in a life tenancy agreement with Miss Jane Smoot since 1973. It is our intention to ultimately develop a historical museum on this site and have been working toward this goal for many years.

The property is a significant cultural asset to the City of Austin and it is our opinion that the flood control plan as presented would adversely affect our property.

This is to serve as notice that our organization is vehemently opposed to your proposal.

We certainly hope that in the future we will be informed in advance of any further actions with regard to your planning for the project or its status.

Sincerely yours,

Jane Hall

Jane Hall
President

cc: Lee Cooke, Mayor, City of Austin
Camille Barnett, City Manager

OLD WEST AUSTIN NEIGHBORHOOD ASSOCIATION
1207 West 10th Street
Austin, Texas 78703

July 25, 1990

U.S. Army Corps of Engineers,
Fort Worth District
ATTN: CESWF-PL-P
P. O. Box 17300
Fort Worth, Texas 76102-0300

Re: Shoal Creek Flood Control Plan,
Austin, Texas

Dear Sir or Madam:

The proposed flood control plan includes a proposal for a tunnel running from Pease Park just east of Pressler Avenue into Town Lake.

If built, this tunnel would adversely impact what may be the most important historical site in our Neighborhood, namely the Smoot Home (also known as "Flower Hill"). This 113-year-old home has recently been purchased by the Austin Heritage Society, and is destined to become a museum.

Although this matter has not yet been formally discussed by our Neighborhood Association, I can assure you that this proposal is likely to generate a great deal of opposition.

Sincerely,

Philip C. Friday, Jr.
Chair, Steering Committee

PCF/sw

bcc: Ms. Jane Smoot

PHILIP C. FRIDAY, JR.
ATTORNEY AT LAW
700 SAN ANTONIO
AUSTIN, TEXAS 78701

AUSTIN TX 787
PM
25 JUL
1990

25

Ms. Jane Smoot

STATE OF TEXAS
OFFICE OF THE GOVERNOR
AUSTIN, TEXAS 78711

WILLIAM P. CLEMENTS, JR.
GOVERNOR

August 18, 1990

Ms. Janis Cullum CESWF-PL-P
U. S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

RE: TX-R-90-06-14-0015-50
Shoal Creek Flood Control

Dear Ms. Cullum:

Attached are subsequent comments received on the above captioned proposal.

If we can be of further assistance, please let me know.

Sincerely,

T. C. Adams
State Single Point of Contact

TCA/pon

Enclosure

POST OFFICE BOX 12428 • AUSTIN, TEXAS 78711 • 512 463-2000

TX-R-90-06-14-0015-50

RECEIVED

AUG 09 1990

GOVERNOR'S BUDGET OFFICE

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

ANDREW SANSOM
Executive Director

COMMISSIONERS

CHUCK NASH
Chairman, San Marcos

GEORGE C. "TIM" HIXON
Vice-Chairman
San Antonio

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Dallas

DELO H. CASPARY
Rockport

JOHN WILSON KELSEY
Houston

BEATRICE CARR PICKENS
Dallas

A.R. (TONY) SANCHEZ, JR.
Laredo

August 7, 1990

Mr. T. C. Adams
State Single Point of Contact
Governor's Office of Budget & Planning
Post Office Box 12428
Capitol Station
Austin, Texas 78711

Re: Shoal Creek Flood Control

Dear Mr. Adams:

Over the past several years staff of this agency have been involved with this project. This has included coordination with the U.S. Fish and Wildlife Service and participation in field surveys. Because of the concern for a reoccurrence of additional flooding, every effort has been made to consider all alternatives and develop a plan that will provide a level of protection from flooding, while also minimizing the effects to fish and wildlife. One major concern of this agency has been to protect Shoal Creek from extensive channelization and other modifications. The plan should provide sufficient base flows in Shoal Creek during times when flows are normal. This stream, while urban, provides a place of refuge for aquatic species as well as birds and small mammals which are found within or near its banks. Terrestrial habitat adjacent to the stream is important to wildlife because it provides a corridor for small mammals and birds to travel through the area.

A major concern with the proposed plan is the two tunnels designed to release water to Lake Austin and Town Lake. Off site disposal of the large volume of material that will be generated should be considered. Also, to ensure that the base flows in the stream are not released through the tunnels, the project should be designed to provide base flows into the main channel during normal rainfall periods.

In a final analysis, the Recommended Plan seems to provide a balance by considering all the factors.

I appreciate the opportunity to review and comment on this project.

Sincerely,

Larry D. McKinney, Ph.D.
Director, Resource Protection Division

LDMcK:RWS:wja

PL-P

OLD WEST AUSTIN NEIGHBORHOOD ASSOCIATION

Resolution Regarding

Shoal Creek Flood Control Plan: Pressler Avenue Tunnel

WHEREAS the Smoot Home (a/k/a "Flower Hill"), located at the corner of 6th Street and Pressler Avenue in Austin, Texas, is an historic home of great significance;

WHEREAS the lower drainage tunnel proposed as part of the Shoal Creek Flood Control Plan would threaten the structural integrity of the Smoot Home; and

WHEREAS other alternatives could be found for the location of the tunnel;

NOW, THEREFORE, BE IT RESOLVED that the Old West Austin Neighborhood Association recommend to the City of Austin, the U.S. Army Corps of Engineers and the Congress of the United States that the lower drainage tunnel be relocated so that it will not pose a danger to the continued existence of the 113-year-old Smoot Home.

ADOPTED unanimously by the Steering Committee of the Old West Austin Neighborhood Association on August 20, 1990.

City of Austin

Founded by Congress, Republic of Texas 1839
Transportation & Public Services, P.O. Box 1088, Austin, Texas 78767-8839
Administrative Offices: One Texas Center, 505 Barton Springs Road Telephone: 512/499-7058

August 31, 1990

Colonel William Brown
Corps of Engineers
CESWF
P.O. Box 17300
Fort Worth, Texas 76102-0300

Re: Shoal Creek Flood Protection Project
Austin, Texas

Dear Colonel Brown:

Thank you for the excellent presentation of the above referenced project on July 18, 1990. The public meeting was informative and handled in a very skillful and positive manner. As a result of that meeting and previous discussions between our respective staffs, we have compiled an updated version of comments regarding this project from my staff, as well as comments from the Environmental and Conservation Services Department and the Water and Wastewater Utility.

Department of Public Works and Transportation

1. Hydrology - We can not support the Corps peak discharges on Shoal Creek. The Corps 25-year peak discharge compares closely with the City's recently completed 100-year floodplain study for FEMA. We believe that the Corps high peak discharges generates a large floodplain that unduly inflates flood damages. It also leads to a design which protects citizens from extremely rare events at a very high cost. This long-standing issue must be resolved to our satisfaction before we make our recommendation to the City Council on the project.

2. US 183/Loop 1 (MoPac) Improvements - A consultant hired by the City of Austin designed the existing 3-9'x5' box culverts for ultimate land use conditions. The four detention ponds located just upstream of US 183 were constructed to reduce ultimate peak discharges to existing levels at that point. Therefore, we can not support the proposed addition of two 11-foot diameter conduits at the highway, since the improved conveyance would reduce the amount of detention storage. This would increase downstream discharges and flooding risk. A letter from the Highway Department is attached, indicating their concerns about the Corps proposed improvements at US 183. The Corps design for this area must be changed to delete the proposed conduits before we make our recommendation on the project.

3. Tunnels - The Corps did not obtain soil borings along the proposed tunnel alignments. Without soil borings, it will be difficult to accurately determine the type of materials encountered and the cost of tunneling. The approximate nature of the tunnel profile graphics, coupled with the historical preservation concerns raised by citizens near the lower tunnel outlet, require that definitive information on this issue be provided before we make our recommendation on the project.

4. Floodplain Reduction - Table 5-1 in the Draft Interim Report, May 1990, provides an estimate of the level of protection provided by the proposed project. Many of the reaches appear to show a marginal or insignificant level of floodplain reduction. It will be difficult to "sell" the project to the citizens of Austin when a perception of questionable flood protection benefits exists. Obvious flood plain reduction benefits need to be shown before we make our recommendation on the project.

5. Project Cost - The City's projected requirement of $20,623,000 is very substantial in a time of economic hardship. Since the citizens of Austin want projects equitably distributed throughout the City, it will be extremely difficult to obtain voter approval of the necessary bonds for this project. Upon satisfactory resolution of all technical issues, we will be able to determine which segments of this project could be recommended from a financing perspective.

<u>Environmental and Conservation Services Department</u>

1. Although the Corps has optimized the water quality impacts with the flood control benefits for the northern tunnel by decreasing the annual average diversion volume, the fact remains that urban stormwater runoff (which likely contains toxic pollutants such as chlordane) would be flowing into Lake Austin, one of the City's water supply reservoirs. Before making a final conclusion on the risk this could pose for Lake Austin, we will do some sampling of the water in Shoal Creek during storm events to determine whether our estimates of pollutant concentrations are accurate. If it is verified that toxic pollutants would be diverted to Lake Austin, we would find it very difficult to support the upper tunnel. Since we do not know whether incorporating additional water quality controls into the tunnel would substantially reduce the impacts of the toxics, the Corps should plan to definitively address this issue if materially affects our recommendation on the project.

   Similar concerns exist about creating a new Shoal Creek discharge point into Town Lake upstream from one of the City's water treatment plants. It is unlikely that pollutant concentrations in Shoal Creek at Pease Park near West 19th Street differ significantly from those

monitored at the West 12th Street bridge. Therefore, the lower tunnel will introduce toxic pollutants to a larger area of Town Lake and, more importantly, to the water supply portion of the lake.

Before we can support the tunnel phases of this project, these concerns about the fate of toxic pollutants and the possibility of implementing control measures to improve the quality of the diverted water must be addressed. We may eventually request that such controls be included if their presence materially affects our recommendation on the project. We would appreciate it if the Corps would provide any additional information it has on these issues in order that we may better prepare our recommendation.

2. The Corps may have additional capability to consider water quality as part of the project. A 1988 report by the North Central Texas Council of Governments: "Summary Report; Regional Initiatives for Storm Water Management", states that:

> "As part of the Regional Environmental Impact Statement for the Trinity River Corridor, consultants to the Corps of Engineers (emphasis added) have identified potential sites for up to 21 wet detention ponds that could remove 40% or more of urban runoff pollutants."

There may be more that the Corps can do to accomplish dual objectives of water quality and flood prevention in the Colorado River Basin. Executive Order 12372 (issued July 14, 1982) as amended (April 8, 1983, Executive Order 12416) calls for States to review federally supported activities and projects to determine if they are consistent with the State's nonpoint source pollution (NPS) management programs. Any federal projects identified for review are required to accommodate, according to the requirements and definitions of the Executive Order, concerns the State may express about consistency of the project with the State's NPS Management Program. The Texas Water Commission has expressed its concerns about the Shoal Creek project in response to the latest Draft Interim Report.

Recent conversations with Bobby Shelton and Janis Cullum have revealed that there is provision for the Corps to participate in water quality improvement projects at the 75% level. This is as opposed to mitigation of impacts of the Shoal Creek project itself. Water quality improvement is certainly a possibility for the discharges to Town Lake.

In light of all of the above information, the Corps needs to provide its reassessment of its ability to financially participate in efforts to improve water quality as part of this project before we can make our recommendation on the project.

3. The latest information provided in the Shoal Creek project report concerning endangered species is correspondence with the U.S. Fish and Wildlife Service dated September, 1989. Since that time, the Golden Cheeked Warbler has been listed as an endangered species.

   Maps produced for the Balcones Canyonlands Habitat Conservation Plan show potential habitat of the Golden Cheeked Warbler, a listed endangered species, near the site of the proposed outlet of the upper tunnel. It is not clear from the report that the potential threat to this newly listed endangered species has been adequately considered. The issue must be resolved before we can make our recommendation on the project.

Water and Wastewater Utility

The Corps of Engineers proposes two diversion channels--one upstream (2.3 miles) from the Davis Water Treatment Plant (WTP) on Lake Austin and the other immediately upstream (0.7 miles) of the Green WTP on Town Lake. We are concerned about any flow diversion which may impact the source of the City's drinking water supply.

The Draft Finding of No Significant Impact (FONSI), on pages EA-12-13, lists a number of pollutants which are potentially harmful to human health and are present in stormwater from Shoal Creek. These include: automotive residues (gasoline, oil, exhaust particulates, etc.), arsenic, copper, lead, zinc, polychlorinated biphenols, chlordane, DDD, DDE, DDT, diazinon, pyrene, PAHs, other pesticides and fertilizers, and various other oils and organic materials. Furthermore, the Draft FONSI also describes the presence of materials which can clog intake screens and filters at the water treatment plants, such as street litter, dust, and other road debris; grass and shrub clippings.

The Draft FONSI states in at least two places, pages EA-13 and EA-44, that, in spite of its pollutant loading, stormwater runoff from Shoal Creek does not significantly affect the use of Town Lake as a city raw water supply.

Shoal Creek waters do not normally affect the City drinking water supply because the raw water intake is upstream on Town Lake from the mouth of the Creek. As the Draft FONSI points out, the adverse impacts of urban development on the stormwater quality in Shoal Creek in the lower reaches is greater than in the upper reaches. Consequently, we are particularly concerned about the 19th Street diversion which will move stormwater from a heavily urbanized part of the City and discharge it just upstream of the Green WTP.

On page EA-47, the water quality at the intake is predicted to "occasionally be affected by the diversions", but, the Draft FONSI states, it "can be easily treated". "As a result, the diversions to Town Lake may increase the treatment cost slightly."

Water containing some of the pollutants described above might not be "easily treated" for use as drinking water. The new Safe Drinking Water Act requirements will mandate that the City monitor for an increasing number of pollutants and remove them if found above certain concentrations. The heavy metals and complex organic compounds mentioned as components of Shoal Creek stormwater could pose a problem from a drinking water supply standpoint. Furthermore, increases in debris upstream of the raw water intakes will result in more clogging of the intake screens and filters at the WTP. The Draft FONSI acknowledges that the costs of treatment may be increased, but how much is "slightly"?

Construction related impacts are discussed on page EA - 48 and are described as causing "dramatic but temporary, water quality problems." The Corps estimates a two year construction time for the 19th Street Tunnel. Although the impact may be temporary, construction-related effects will seriously affect the cost of water treatment at Green WTP because of the increased sediment and debris which will enter Town Lake upstream of the raw water intake.

Construction of the Northwest Park Tunnel is estimated to take three years for completion. Debris and sediment from this project could also affect the raw water intake at Davis WTP on Lake Austin.

In summary, the Utility is very concerned about potential impacts on its drinking water supply from the proposed diversion of Shoal Creek stormwaters to areas upstream of water treatment plant intakes. Our recommendations are that, if the project is to continue, a more detailed analysis of water quality impacts on the City's drinking water supply should be conducted and that serious consideration be given to diverting the stormwater flows to discharge points downstream from both water treatment plant intakes.

<u>Overall Conclusion</u>

At this time, City staff cannot recommend approval or the issuance of a letter of intent regarding the proposed Shoal Creek Floodplain Management Plan until the above comments are resolved to the satisfaction of the concerned departments.

CORPS OF ENGINEERS RESPONSES TO
CITY OF AUSTIN COMMENTS ON
SHOAL CREEK

Department of Public Works and Transportation

1. Hydrology

On 15 Jul 87 there was a meeting in the Fort Worth District Offices concerning the hydrology to be used for Shoal Creek for the Flood Insurance Study and for the Corps planning study. At that time the Corps of Engineers was the study contractor with FEMA to do the FIS for Shoal Creek. Our time and cost to FEMA for this study had included our using the planning study results computed probability discharges.

In attendance at the meeting were: Greg Toth of the city of Austin; Duke Altman of Espey, Huston Associates (studying Shoal Creek for the city of Austin); Ken Davis of FEMA; Paul Rodman, Jim Medlock, Jim Graham, Kevin Shafer, Greg Estep and Tom Vogt of the Fort Worth District Corps of Engineers.

Greg Toth indicated that Ramon Miguez, city of Austin, had offered to have the city to do the complete FIS for Shoal Creek. After considerable discussion of public perception problems which might result due to different hydrology and hydraulics with the city of Austin producing the FIS and the Corps having significantly larger discharges for the planning study, it was agreed to let the city of Austin studies be used for the FIS. As a condition to that agreement, Greg Toth agreed that the Corps would continue to use the results developed in accordance with Corps criteria for the planning study.

We have reviewed our hydrology studies and compared them with the most recent studies (1982) which the city of Austin has supplied to us. After reviewing historical events and comparative USGS frequency discharges, our 25-year and more rare events seem reasonable, if not too low. The 3-hour rainfall duration used by the city is not long enough for evaluating volume of frequency events for detention storage. Rainfall studies for 24-hour duration have indicated that we could have justified using an even greater 24-hour rainfall total than was utilized with this study. Our model produced a lower computed peak for the 1981 event than was observed, again supporting the idea that we are too low for rare events. Comparing frequencies of rainfall and observed discharges in the 1981 event with computed frequency discharges supports the reasonableness of the Corps model for rare events. In short, we feel that the data available support the higher discharges of the Corps planning study. We will be happy to consider any arguments and additional data from the city of Austin. We also request a copy of their current hydrology writeup and results.

2. US 183/Loop 1 (MOPAC) Improvements

The enlargement of the culverts under Highway 183 were incorporated in the Corps design recognizing the detention ponds upstream and channel improvements both upstream and downstream of the road. Although a minimal increase in

downstream discharges would occur from the Corps project, the improved channel conveyance downstream is more than adequate to handle the increase. Our analysis concluded that the detention ponds will reduce the projected increase in discharges to existing levels as you suggest. Therefore, existing discharges were used to design and justify the project.

3. Tunnels

Available soil information was utilized in the analysis. Geological information on tunneling in the Austin area was also utilized. The estimated construction cost has included adequate contingencies to provide for a reasonable amount of possible construction problems. Soil borings will be made during the design memorandum phase. Subsidence of structures at the surface will not occur.

4. Flood Plain Reduction

The percent of damage reduction for the project is also shown in table 5-1 by reach. The percentage of damage reduction for the majority of the reaches is over 80 percent. The overall project has a reduction in flood damages of 83 percent. It must be recognized that it is not economically possible to provide complete protection to everyone in the watershed.

5. Project Cost

As we have discussed in the past, any project would most likely have to be approved by the voters through a bond election. The outcome of such an election is impossible to predict at this time. Additionally, phased construction could spread the project costs over an acceptable timeframe.

Environmental and Conservation Services Department

1. Water Quality

a. It is our opinion that the diversion waters will not transfer significant quantities of nutrients or toxic contaminants to Lake Austin. (Although chlordane has been identified in fish tissue in Town Lake, it would be overly conservative to assume that this substance would be in significant concentrations in Shoal Creek diversions to warrant concern for several reasons. The source of chlordane contamination in Town Lake has not been determined and may never be determined. It would be difficult to correlate that chlordane is in significant concentrations at the point of Shoal Creek diversions. Likely source or sources of chlordane would be nearer to Town lake where there are a higher density of residential/commercial buildings and pavement. This consideration should not be limited to just Shoal Creek, but should include all streams entering Town Lake that have heavy urbanization in their lower watersheds. Chlordane has been banned for public use as a pesticide for several years, and concentrations, if present in the upper watersheds surrounding Town Lake, would diminish with time. Therefore, it would be difficult to infer that the diversions will carry significant

concentrations of chlordane to Lake Austin. Although there is a public health advisory against the consumption of fish because of chlordane, Town Lake is still being used as a water supply reservoir for drinking water.)

It is our observation that because of the current condition of Town Lake, the diversion of Shoal Creek waters to Lake Austin is not wanted by the city. Yet, Town Lake receives "urban runoff" and is still used as a drinking water supply source. We were recently told by Mr. John Parish at a recent meeting with Lower Colorado River Authority that the city has no plans to discontinue using Town Lake as a water supply. It appears that the concern for toxics in Town Lake is not important enough to discontinue its usefulness. Based on this inconsistency, it is difficult to ascertain what the city's drinking water quality philosophy is.

Lake Austin is not pristine like Lake Tahoe. It, although having better quality than Town Lake, does receive some "urban runoff". Lake Austin receives enough nutrients to be eutrophic as many lakes in Texas are. The diversion of water from Shoal Creek will not significantly worsen the lake's eutrophic state. Though slightly worse than Lake Austin, Town Lake does easily support fish and other aquatic life.

We commend the city's commitment to sample the Northwest Park area to determine if the your estimates of pollution concentrations in diversion waters are accurate. However, we are uncertain as to what is meant by "If it is verified that toxic pollutants would be diverted to Lake Austin, we would find it very difficult to support the upper tunnel." We hope that an unquantifiable presence of a substance is not the immediate grounds for determining whether to support the upper tunnel. Based on water quality sampling data, there are trace toxics within Lake Austin. However, this does not constitute a major concern, since concentrations are low. Diversions should be evaluated with at least the same considerations. Toxic analysis should also include whether the toxic is tied-up in sediment or in a dissolved form. Your sampling program should include a sufficient number of samplings during diversion magnitude events (that may occur once or twice a year) to determine whether a contaminant's presence is anomaly or a reoccurring concern. This type of sampling may take several years before a useable database is acquired. If sampling and subsequent analysis shows that there is, in fact, a contaminant of concern, this should not be the sole basis to reject the inclusion of the upper tunnel. If a toxic's presence is frequent, measures should be taken to locate and properly treat/dispose of the source upstream. If Town Lake is to be continued as a drinking water source, this should be done regardless of the Shoal Creek flood control project.

To further help identify probable sources of pollution on Shoal Creek, we suggest that you review the "Nonpoint Source Water Pollution Management Report for the State of Texas" (Texas Water Commission et al., undated draft, but probably completed in 1988). This report states that "While Shoal Creek appears to have problems with meeting State water quality standards for fecal coliforms (at 12th Street), the primary source of the problem seams to be

related to point sources, i.e., the wastewater collection system within the watershed." In conclusion, the report recommends:

> "...The City should target the Shoal Creek watershed for intensive evaluation and rehabilitation under these programs (the City's wastewater repair and rehabilitation program and the extensive television inspection program).
>
> Although nonpoint source pollution is not a primary source contributing to a violation of the State water quality standards in Shoal Creek, sedimentation, litter, algae, and oil and grease were commonly noted in field investigations. While the city of Austin presently regulates storm sewer discharges and requires erosion controls within the watershed, the City and/or other public agencies may wish to further evaluate options to address those identified visual pollutant concerns in the creek. Shoal Creek is not recommended as a priority nonpoint source water shed at the Statewide level."

b. Diversions through the lower 19th Street tunnel will enter Town Lake about 0.7 mile upstream of the raw water intake for Green Water Treatment Plant on Town Lake. The stilling basin option at the tunnel outlet would reduce flow velocities to prevent scour. A large portion of the suspended sediment would settle as the flows reach Town Lake. However, this option would probably still permit a minor portion of diverted suspended sediment load to reach the intake structure. The recreational lagoon option at the tunnel outlet would significantly reduce sediment loads of diversion waters over the stilling basin option and likely improve the overall water quality of Town Lake. Another possible consideration for reducing the potential uptake of diverted suspended sediment is the addition of a wall or berm on the upstream side of intake structure.

c. Due to limited funding, the above information and the previous water quality analysis submitted in the previous Corps report are all that we can furnish at this time. We suggest that if you have need for additional water analysis that you solicit your congressman for funds or perform your own water quality analysis and submit the findings to the Corps. Your sampling program could provide an initial step to answering the concerns that you have.

2. Water Quality Enhancement

a. The Trinity River Regional Environmental Impact Statement study was conducted to assess cumulative impacts of development projects in the Upper Trinity River floodplain within the Dallas/Fort Worth Metroplex and to assist the Corps in formulating criteria for the evaluation of future Section 404 permits in the area. Flood control improvements are currently being investigated for the Upper Trinity River in a cost-shared feasibility study. Potential water quality enhancement measures are also being considered in this study in accordance with the Water Resources Development Act of 1986.

b., c., & d. The Corps has the authority to further study water quality enhancement features with the Shoal Creek flood control project, but does not have the funds available to conduct such studies at this time. We agree there is a potential for the water quality enhancement measures to be incorporated with the discharges to Town Lake.

3. Golden-cheeked Warbler

a. On page EA-16 of our May 1990 environmental assessment, the golden-cheeked warbler is listed with the other endangered species. Since the species was just placed on the Federal Emergency List for Endangered and Threatened Species on May 4, 1990, this office was only able to receive a verbal indication from US Fish and Wildlife Service (USFWS) that the species would not be affected by the proposed project.

b. At the USFWS office, we compared the project construction sites with USFWS habitat maps for the golden-cheeked warbler. According to this mapping, the upper tunnel outlet is near the species habitat. However, golden-cheeked warbler habitat would not be affected, because the outlet/stilling basin construction is located on the side of a vertical cliff and through a previously cultivated field. The species is more suited to habitat having a mix of mature ash juniper and oak. Therefore, USFWS has verbally concurred with the proposed project having no effect on the species.

Water and Wastewater Utility

a. We would have greatly appreciated your department's input in the earlier study stages when some of your concerns could have been better addressed in earlier drafts of the Environmental Assessment (EA). Perhaps, your earlier review and input could have aided our plan formulation.

b. We recognize your concerns over the locations of tunnel outlets upstream of the city's intake structures. As cited on pages EA-12 and EA-13 of the EA (not the Draft Finding of No Significant Impact), there are several contaminants of concern in Shoal Creek waters. Most of the contaminants are common in urban runoff of other area watersheds as well. Better watershed management practices could go a long way to reducing these contaminants of concern. An initial step is the undertaking of the TWC recommendations (as discussed above under response to Environmental and Conservation Services Department comment 1.a.) to evaluate and repair leaking wastewater mains. Periodic clean-up activities along Shoal Creek would potentially improve not only the water quality for diversions, but also improve the water quality for Town Lake.

c. We acknowledge that the EA (not the FONSI) states that "Shoal Creek waters enter Town Lake but do not significantly affect the use of the lake as a city raw water supply."

d., e., & f. See the Corps response to Environmental and Conservation Services Department comment 1.b.

g. & h. The upper diversion outlet on Lake Austin is relatively distant from the Davis Treatment Plant. Shoal Creek diversions through this outlet would have no significant impacts on operations of either treatment plant on Lake Austin. Construction activities would temporarily disturb waters adjacent to the outlet areas. Although construction activities may last as long as 3 years, sediment and erosion control measures would prevent any serious disruption of treatment plant operations.

i. We agree that your concerns warrant further attention; however, there are no funds to continue further water quality investigations. We, too, would desire the relocation of the tunnel outfalls; however, it is not economically feasible to construct the outlets downstream of the city's water supply intakes.

CESWF-PL-P (1105)

26 Oct 90
Murphy/4-3876

MEMORANDUM FOR RECORD

SUBJECT: Meeting with city of Austin to Discuss Shoal Creek, Austin, Texas

1. A meeting was held on October 15, 1990, with representatives of the city of Austin to discuss the city's concerns with the proposed project. The following people were in attendance:

Bill Stockton	COA	Public Works	512-499-7037
Tom Hegemier	COA	Public Works	512-499-7104
Frank Houston	COA	Public Works	512-499-7102
Steve Stecker	COA	Environmental Cons.	512-499-2550
Colonel Brown	COE	District Engineer	817-334-2300
Bill Hill	COE	Planning	817-334-2201
Bobby Shelton	COE	Planning	817-334-2095
Jo Ann Crane	COE	SWD-Planning	214-767-4523
Terry Coomes	COE	Engineering	817-334-2179
Mike Mocek	COE	Project Management	817-334-3565
Mike Ensch	COE	Executive Assistant	817-334-2301
Tom Vogt	COE	Planning	817-334-3876
David Wilson	COE	Engineering	817-334-8461
John Hickman	COE	Engineering	817-334-2852
Ron Hula	COE	SWD-Engineering	214-767-2390
Paul Rodman	COE	Engineering	817-334-3134
Jack Hussey	COE	Engineering	817-334-2311
Janis Murphy	COE	Planning	817-334-3876

2. The meeting opened with Colonel Brown summarizing the issues which were to be discussed. Colonel Brown discussed the three major issues. These are hydrology, cost and water quality. However, if the hydrology issue is not resolved, it will be difficult to proceed with the project. It really boils down to hydrology and all other issues. As far as the hydrology issue, there are differences in discharges between the Corps' numbers and the city's numbers. What the Corps uses is expected probability discharges, which are somewhat higher than normal. The process which the Corps must use to get the report processed and through the system is outlined in regulations, and the information which has been developed and utilized in the report is in accordance with policies. There is not much flexibility in the process for changes. As far as water quality is concerned, it appears that there is the potential for environmental enhancement to be added to this project. At this time there is no more money to do any analysis on this issue. The analysis which has been done has shown that the water quality effects are not significant. If the city has some additional data which would show anything else or if a sampling program was begun, that would be helpful. The Corps realizes that the city is financially in a bind right now, however, this will not be a permanent condition and in any event the city will most likely have to put this on a bond election.

2. Mr. Stockton made a few opening remarks about the city's position on the project. He discussed the city's financial problems. He plans to make a

presentation to the city council in 6 to 8 weeks and at that time he needs to assure them that this is a good project in the staff's eyes. The city needs to be sure it is getting its money's worth. The hydrology is a major issue to the city, however they did not realize the Corps had to have the review and to meet the criteria and review process which Colonel Brown described. The city is interested in downsizing the project. They were under the impression that they had to take it all or none. There are the water quality concerns associated with the tunnels, however the Hancock Creek channelization is completely separate. There can be refinements in the GDM, but there will be more of a chance to delete increments than to change the size of the tunnel. There are basically four components to this project. Notwithstanding the water quality concerns, the city would phase the project components in the following priority order:

1. Hancock Creek
2. Shoal Channel
3. Northwest Park Tunnel
4. 19th Street Tunnel

The reason for ranking Hancock Creek first is because this area has not received any attention from the city and there is more of a noticeable change in the flood plain resulting from the improvements. In the areas along Shoal Creek where there is less of a noticeable change in the flood plain, it will be more difficult to sell the project to the residents. If the 25- or 50-year events had been plotted there would have been more of a change in the flood plain. The percentage reduction in each of the reaches is important to note. This information is shown in Chapter 5 of the report. The issues associated with the lower tunnel are that it is upstream of the Green Water Treatment Plant and it would traverse under an historical area. There needs to be some geotechnical surveys done in this area. The city is not sure that geotechnical information and good engineering will overcome the neighborhood groups. The Shoal Creek channel and Northwest Park tunnel really go together. The increase in flows through the channel really need the tunnel at the end of the channelization. Our analysis looked at adding the tunnel first and then the channel, but did not analyze the reverse order. The city does not want any work to go under US Highway 183. In the 1981 flooding, the water flooded around the railroad tracts and flooded a lot of structures. The city has done some work in this area, however our analysis shows some additional culverts are needed to prevent this from happening again.

3. After these general discussions, the hydrology issue was discussed. The city's hydrology is dominated by short duration storms. They use a 3 hour storm. The Corps uses a 24 hour storm. The city uses a higher infiltration rate than the Corps uses. The Corps also uses expected probability in the computation of discharges for the planning reports. This translates into about a 25 percent increase in discharges. There was a brief discussion of these differences, however it appears that it would not be possible for the Corps to get a different methodology for discharges approved. The city agreed with this. One approach to the difference would be for the city to show the

flood reduction using their analysis. In all likelihood, this would mean that the project would provide a higher level of protection than the Corps indicates. The final recommendation on this is to leave the discharges for both the flood insurance study and the feasibility report as they are.

4. The cost issue was discussed next. The Corps realizes that the city will have to put this project on a bond election and there is always the chance that it can fail. A letter of intent does not legally obligate the city. Mr. Stockton indicated that the earliest this could go on a bond election is in the spring of 1992. The size of that election may depend on the economy. It could possibly be 1994 or 1995 before it is put on a bond election. The current thinking of the city is to get approval from the city council and then to go to the voter in two increments. This will allow the city to analyze the project and then to let the public see some construction. There is a $25 million annual cap on bond sales, and generally the Public Works Department gets $17 to $20 million of the bonds. There is some reservations about having another bond election now since there are still $50 to $60 million in bonds unsold, some from 1984. The city's next priority with bonds will most likely be on street improvements instead of drainage improvements.

5. From the Corps perspective, the GDM may need to be rethought. There may be some added cost associated with the delaying the lower tunnel. It would be unlikely that the city would put more than $10 million on a bond election for this project. One item which would be helpful with selling the project would be to run the 1981 flood event on Shoal Creek with the project in place. The whole key will be to make the project sellable for the city.

6. The water quality issue was discussed next. Bobby Shelton discussed the Corps ideas on this issue. From a water quality perspective, the recommended plan is significantly different from the project proposed in 1987. The changes made in the plan were changes in the outlet locations to minimize the water quality problems. From an overall perspective, the tunnels are a much better option than the channels. The U.S. Fish and Wildlife Service has had very little concern about this project. The analysis which has been made on water quality is based on the information which the city has provided. Any sampling programs which are undertaken by the city at this time could take several years to make any type of determination. The samples will have to be taken during the flood events. The analysis used in the report is a simple mass balance. This was simplified, but there was not sufficient time to do any sampling or sufficient funding to do any more detailed analyses.

7. The city has been very involved in water quality issues in the last few years. They are working on an Urban Watershed Ordinance to control nonpoint source pollution in the watersheds in the city. They have a grant from EPA to study Town Lake. The city council will want a guarantee as to aesthetics, water quality, and environment. They will want to know how often the Green Water Treatment Plant will have to be shut down.

8. The city indicated they would be implementing a water sampling program on Shoal Creek. Their plans are for a random sampling program. The only problem with this is that the flood events can be missed. An automatic sampling program is expensive, and it has some of the same problems, since the bottles must be removed.

9. The lagoon area at the end of the 19th Street tunnel will probably do a lot to help with water quality, however no models have been made. The city feels there must be a water quality improvement on Shoal Creek to make the project sellable. The city has the capability to do nonpoint source analysis, however, right now their emphasis is on Barton Creek and Town Lake. The SCS has just completed a study on water quality for this area, however it does not have any data other than the information the city used to optimize the bypass rate for the upper tunnel. One approach might be to use a worst case analysis. We know the information we have right now for 12th Street is probably worse than at Northwest Park, so if that data was used it would be a worst case analysis. The city is working on a model for Lake Austin. They do not have a model for Town Lake. They do not have enough information at this time to do any analysis.

10. There was a discussion on approaches which could be used to proceed with the project. The city's problem is that they need to convince the council that there will not be any significant impacts to water quality in either lake. Based on the information available now, it may be possible that the city will be able to tell the council that a simplified analysis has been made and is indicates that there are no significant impacts. It will take x years and X dollars to be able to guarantee the impacts of the project. There was a brief discussion about haw much analysis can be done in the GDM. The Corps' would propose to approach it as a water quality enhancement to the project. The project will need to have water quality as part of the authorized project.

11. It was finally decided to determine what activities belong in the GDM and what both the Corps and the city can do now to tie down the water quality impacts. Within a couple of weeks or by the end of October, both the city and the Corps will write up an approach to the issue and then work from there.

12. There was a very brief discussion of the Letter of Intent. Mr Stockton wanted to know what needs to be in the letter. Basically the letter needs to state that the city supports the project and realizes the financial responsibilities of the project, as well as agrees to comply with the items of local cooperation listed in the report. Mr. Stockton wants to include that they may want to phase the project and that it will be contingent on a bond election. We have several examples which will be sent to the city by the end of October.

J. C. Murphy

Janis C. Murphy, P.E.
Flood Control Branch

Shoal Creek Water Quality Study
Preliminary Work Proposal
26 Oct 90

For the purposes of the Feasibility Report, the U.S. Army Corps of Engineers at the Fort Worth District considers the water quality evaluation as sufficient and complete. There are no funds available to extend this study. However, the Fort Worth District does recognize the need to perform some additional water quality analyses to optimize project design during the Design Memorandum Phase, subject to higher approval authority. To accomplish this, the City would be asked to provide the Corps with all the necessary water quality sampling data. The following work plan is preliminary and is subject to further revision subsequent to City and higher Corps review.

We acknowledge the City is committed to conduct a water quality sampling program. Per conversation with Mr. Bobby Shelton of our office, Mr. George Chang of the City indicated that the present plan would include taking a few samples a year. He also stated that sampling could be adjusted if the data would be used in a computer modelling effort.

After further review, we recommend the following plan:

1. City Sampling Program - Recommend that the City take samples oriented toward storm events.

   a. The program should include two sampling stations - one at NW Park intake diversion area and one at 19th Street intake diversion area.

   b. Multiple samples should be taken instream at diversion sites at the onset of the storm, during the storm at peak flow, and as the water elevation lowers instream. At least three samples should be taken at each station for each storm sampled. Four to six samples is optimum for each station storm event. Time of day (hour and minutes) should be recorded for each sample.

   c. Given the current design memorandum study schedule, samples should be taken within 18-month period (beginning now). We recommend that 4-6 storm events be sampled during that period.

   d. Conditions prior to each storm event sampled should be documented. Antecedent conditions to be documented should include (1) how much time has passed between the sampled event and the just previous storm event (with rainfall amount if available), (2) seasonal conditions, (3) date of sampling, and (4) identification of any upstream watershed activities/events that might have affected water quality during sampling (accidental toxic spills, illegal dumping, sewer repairs, etc.).

e. Identify instream flow in cfs during the instant that each sample is taken.

f. Water sampling should be in sufficient detail to conduct modelling, if necessary. Water samples to be tested should include the following parameters:

TSS
TDS
BOD_5
Heavy Metals
Pesticides
Total Phosphorus
Total Nitrogen
Nitrates
Ammonia
TKN
Fecal Coliforms
Total Organic Carbon
Temperature
pH

g. Sediment samples for metal and pesticide testing should be taken at near diversion areas where stream sediment has accumulated.

2. Reservoir Information - the City of Austin should provide the Corps will detailed information of Lake Austin and Town Lake for water quality modelling if needed.

3. As part of the Design Memorandum Phase, the Corps will address water quality concerns from a design perspective. This may include a short descriptive narrative of the findings of sampling program or a detailed analysis if samples show apparent water quality problems with diversions.

4. The Corps will model the effects to Lake Austin and Town Lake if sampling data indicates a potential for significant problems associated with diversions and if the pollutant source is not easily identified for remedial action. The modelling approach will largely depend on what sampling data is available. Here are a few of the possible Corps models under consideration:

a. Use the Corps Hydrologic Engineering Center's HEC-5Q model to determine what effect diversion waters would have on Lake Austin and Town Lake. This model is a one-dimensional and can be used for steady and unsteady state flow regimes. For stratification conditions, the model assumes complete mixing for vertical layers. If there is no stratification, the model can also be used to determine contaminant concentrations downstream. It works well with conservative contaminants that do not degrade rapidly in the natural environment. It can be used in either of two modes for water quality simulation.

One of these modes requires detailed data for 8 parameters to determine phytoplankton effects on dissolved oxygen. The other mode simulates temperature, 3 conservatives, 3 nonconservatives (of which only 2 can be oxygen demanding substances) and dissolved oxygen. The latter mode would probably be used. This model has limited applications for this study, but is significantly cheaper to run.

b. Use the Corps Waterways Experiment Station's CE-QUAL-W2 model. This model is a two-dimensional laterally concentrations both vertically and downstream. This model is very expensive to run compared to the simpler HEC-5Q model. However, it could provide more information in regards to contaminant concentrations.

c. Use the Waterways Experiment Station's RECOVERY Model to determine the effect of a lagoon or conventional stilling basin on diversions to Town Lake. The model could be used with HEC-5Q model to determine potential effects to Green Water Treatment Plant.

d. Piggy-back onto some the city's other modelling efforts involving Lake Austin and Town Lakes. (Dr. Armstrong's study at UT or the recent modelling effort proposed by the Environmental and Conservation Services Department involving the SWM and WASP models). Input project features into these models.

e. Use a Corps consulting firm under contract to conduct the necessary modelling if sampling results show need.

Shoal Creek of Engineers Project
City of Austin
Preliminary Water Quality Proposal
November 14, 1990

Representatives of the City of Austin's Environmental and Conservation Services, Public Works, and Water and Wastewater Department met to draft a water quality study scope for the above referenced project. Two issues were kept in mind during project scope development, a comprehensive study to ensure a high level of confidence in the results and economy. The proposed scope is presented below:

1. The City will perform grab samples at Northwest Park for the next two or three storms this Fall. Of special interest, is the concentration of toxics in stormwater runoff. It may be that these samples will reveal no substantial amounts of toxic materials. This may be sufficient to support the Corps FONSI from a lake water quality standpoint.

We would like to see what the monitoring shows and take additional steps one at a time. Further involvement would depend on the severity of the problem, the ability of the Corps to participate financially and our own financial capability as well.

Recommended plan if above monitoring fails to present conclusive results.

<u>Lake Austin</u>

1. Implement storm sampling station at Northwest Park. Flow proportional sampling will be required for 8 to 10 storms. Sampling by the USGS at the 12th Street station will be done simultaneously for at least 4 storms.

2. Perform sediment sampling at 7 to 10 sites along the length of Shoal Creek to locate toxic "hot spots" (if any). Two of these sites should be located on Hancock Branch.

3. Develop a SWMM4 model of the Shoal Creek watershed to Northwest Park. The water quality forecasting will be calibrated to the above performed stream sampling. Incorporate best management practices (BMP's) to determine water quality enhancement and costs.

4. Upgrade the Lake Austin WASP3 model to WASP4 and TOX1/WASP. Calibration for storm runoff will require intensive lake sampling for several storms for various discharge conditions from Lake Travis. Also, dye studies should be performed to evaluate mixing effects.

5. The City's Water and Wastewater Department will perform a mass balance study from the above results to determine the impacts of the Northwest Park Tunnel on treatment costs.

6. If a more detailed analysis of the effects on Lake Austin is needed, then the entire Lake Austin watershed would be modeled with SWMM4. This would require additional sampling on Bull Creek and small Lake Austin tributaries.

Town Lake

1. Perform water quality sampling at the 12th Street bridge to compare past data with future data.

2. Obtain Town Lake samples a distance downstream from the current Shoal Creek confluence that equals the distance from the proposed 19th Street Tunnel outfall to the Green Water Treatment Plant. This approach should closely approximate the mixing in Town Lake.

3. The above samples will be utilized in City Water and Wastewater analysis to determine impacts of the 19th Street Tunnel on water treatment costs. Samples from step 1 will provide a worst case analysis.

4. Performance of SWMM4 modeling down to 12th Street would give more accurate results for both the Northwest Park Tunnel and the 19th Street Tunnel.

5. WASP4 and TOX1/WASP modeling of Town Lake may be needed to evaluate the water quality impacts of the 19th Street Tunnel for periods of 1 to 30 days after a storm.

001743

BRUCE TODD
MAYOR

OFFICE OF THE MAYOR

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AUSTIN, TEXAS 78767
A/C 512 499-2250
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July 12, 1991

Colonel William D. Brown
District Engineer
Fort Worth District, Corps of Engineers
P. O. Box 17300
Fort Worth, Texas 76102-0300

Subject: Shoal Creek Flood Control Project

Dear Colonel:

The May 1990 Draft Interim Report and Environmental Assessment for flood control improvements along Shoal Creek in Austin, Texas have been reviewed by the City of Austin. In the report, the 14-foot combination tunnel/channel plan is identified as the National Economic Development plan, in accordance with federal guidelines. This recommended plan includes the Northwest Park Tunnel, the 19th Street Tunnel, and two channelization projects (one in the upper reaches of Shoal Creek and the other in Hancock Creek).

The City hereby expresses its desire for the federal government to proceed with the design of the Hancock Creek channelization segment of the recommended plan. The City requests that environmental protection enhancement measures be considered for this segment in accordance with Section 306 of the Water Resources Development Act of 1990.

The City has the authority and capability (through a bond election) to meet the requirements for non-federal responsibilities for the Hancock project as identified in the report and in future legal documents. The City intends to submit the Hancock project to a bond election at the appropriate time. If that bond election is approved by the voters, the City will use the bond funds in a timely manner to meet its obligations. Funds to operate and maintain the project after construction will be provided through the City's annual budget. However, this letter does not obligate the City to provide any funds nor make any expenditures until such time as the Local Cooperation Agreement for this project is executed.

We look forward to continuing to work with the Corps on this project. Please feel free to contact us if you have any questions.

Sincerely,

Bruce Todd
Mayor

APPENDIX B

ARCHEOLOGICAL ASSESSMENT

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APPENDIX B

ARCHEOLOGICAL ASSESSMENT

SHOAL CREEK
AUSTIN, TEXAS

INTRODUCTION

On October 7-9, 1985, a cultural resource field survey of the Shoal Creek project area in Austin, Texas, was conducted as part of the Shoal Creek flood control study requested by the city of Austin. Additional field study of the proposed tunnel intake and outlet locations was carried out on November 21 and 24, 1986, although the outlet locations proposed at that time for Laguna Gloria and Dry Creek areas have since been relocated. In April 1989 field reconnaissance took place at a location for the southern tunnel outlet proposed below the junction of West Lynn Street and West 5th Street, and basic archival checks were made on this location and the tunnel outlet proposed at the confluence of Bull Creek and Lake Austin. Additionally, information on historic Pease Park was obtained from the Austin History Center.

The following discussion covers four sections: (1) a report from the 1985-1986 studies, (2) a report on the 1989 field visit, (3) a general summary of what is known to date, and (4) objectives remaining for cultural resource studies.

1985-1986 FIELD STUDIES

The 1985-1986 cultural resource inventory was comprised of a records search and a pedestrian survey of the Shoal Creek study area in order to provide a complete inventory of all historic and prehistoric sites.

This survey sought to locate and record all historic and prehistoric remains within the study area, and to formulate a plan to minimize adverse impacts to these resources.

The Shoal Creek study area begins approximately 3,000 feet north of U.S. Highway 183 near the Balcones Research Center and runs south for approximately 12 miles to the Colorado River. The area studied included channelization and/or two tunnel diversions, but excluded the present (1989) tunnel outlet locations. A total of five prehistoric and/or historic archeological sites were previously recorded in the project area. Two additional sites were recorded during this survey.

A file search for previously recorded historic and prehistoric sites was conducted through Texas Archeological Research Laboratory (TARL) and the Texas Historic Commission (THC). Ms. Carolyn Spock aided the search at TARL and Ms. Nancy Kenmotsu provided much additional information from the THC.

The entire length of Shoal Creek, from north of U.S. Highway 183 and the MOPAC Railroad junction, south along the creek to the Colorado River was surveyed October 7-9, 1985, on foot during reasonably good weather conditions. Photographs were taken at informative points.

Survey strategy involved inspecting both sides of Shoal Creek for its entire length (approximately 12 miles) for evidence of cultural resources that might be affected by the maximum channel with a 45- to 90-foot bottom width. The three proposed intake areas at Northwest Park, Hancock Creek just upstream of the shopping center, and Shoal Creek downstream of 45th Street were also inspected.

Information on several previously recorded archeological sites and other sites of significant historic interest was obtained from the search of records for the study area. Sites 41TV53, 54, 55, 137, and 298 are located along Shoal Creek and within the study area. Additional cultural resources 41TV47, 41TV261, 41TV337, and the Laguna Gloria National Register Property are here identified as earlier reported but no further discussion is needed in view of the now shifted proposed tunnel outlets.

41TV53. Prehistoric. Nitsche Midden site between Shoal Creek and Hancock Creek, 1/4 mile south of Hancock Drive. Now covered by residential development, it is uncertain whether any parts of the site remain intact. No cultural materials were located. The site is out of the area of project impact.

41TV54. Prehistoric. Campsite between Shoal Creek and Hancock Creek, 1/4 mile downstream on Shoal Creek from Hancock Drive. Now covered by residential development, it is uncertain whether any parts of the site remain intact. No cultural materials were located. The site is out of the area of project impact.

41TV55. Prehistoric. Campsite on Shoal Creek downstream from the confluence of Hancock Creek. Now covered by residential development, it is uncertain whether any parts of the site remain intact. No cultural materials were located. It is out of the area of project impact.

41TV137. Historic. Lamar Street Dump Site. On the hill slope above Lamar Street in the vicinity of 26th and 27th Streets. Late 19th and early 20th century dump location for the city of Austin. An historic outcrop along Shoal Creek north of 24th Street is believed to be a component of the Lamar Street Dump. The heavy concentration of artifacts near the channel would be affected by any channelization on the eastern side of the present stream.

41TV298. Historic. Late 19th and early 20th century house and pen located on west side of the MOPAC railroad north of U.S. Highway 183. The site was not found, and appears to have been razed by bulldozers.

Seiders Oaks. The marker for this "Recorded Texas Historic Landmark," Seiders Oaks, depicts the site of an historic settlement and massacre by Indians located on the hike and bike trail on the west side of Shoal Creek

at 35th Street. Several varieties of native Texas oaks date to the historic settlement situated along an old wagon trail, now the hike and bike trail. The inscription is shown below.

Seiders Oaks

Site of 1839 Home and
1842 Massacre of Gideon
White. A daughter, Louisa,
Wed (1846) Edward Seiders
For Whom Oaks are Named.
Recorded Texas Historic Landmark, 1967.

View of Seiders Oaks Texas Historic Landmark and Location of White/Seiders Home Site on west side of Shoal Creek.

Two springs, Seiders Springs, are present at this location. In 1839 they were described as a possible water supply for the new capital. Fort Austin and other army camps used the springs between 1847 and 1865. Notables such as General Robert E. Lee and General George A. Custer camped at the springs along with their troops (Daily American 1967). The springs became a popular resort and a bath house was operated by the Seiders

family until 1896 (Brune 1981). Subsurface remains are highly likely in this segment and might be affected by channelization, but not by the tunnel alternatives.

Seiders Spring, East Side of Shoal Creek Along Hike and Bike Trail at 35th Street

Several historic districts are located near the Shoal Creek project area in the vicinity of its confluence with the Colorado River. The Bremond Block Historic District and Congress Avenue Historic District lie east of the Shoal Creek and Colorado River confluence and the Clarksville Historic District lies west of this same area (Steeley 1984). These historic districts should be unaffected by channelization.

A previously unrecorded archeological site was discovered during the field survey. The new site, 41TV1293, consisted of a scatter of historic

material on the east bank of Shoal Creek just south of 29th Street. Material noted included purple glass, whiteware ceramic sherds and crockery sherds. It is not known if the material is related to a historic homesite or a refuse feature. Further evaluation should take place if a project alternative is chosen that would affect it.

Other isolated artifacts and two small historic scatters were not defined as sites. The historic scatters seem to be small dumps at the stream edge.

An historic dam, the Franz Fiset Dam, was observed on Shoal Creek just below 49th Street. The dam appears to be cut rock (probably limestone) and is approximately 12 feet high and 30 feet in length.

View of Franz Fiset Dam on Shoal Creek just below 49th Street looking South (Downstream).

The 1985-1986 pedestrian survey revealed that much of Shoal Creek is heavily developed by both residential and commercial facilities. Seven recorded archeological sites, the Mormon Mills Springs settlement, the

Seiders Oaks Texas Historic Landmark and the historic dam are located in areas that might be affected by channel improvement plans. Sites 41TV53, 54, and 55 in the area between Shoal Creek and Hancock Creek are considered damaged and possibly destroyed by residential development. No evidence of these three sites was apparent during the survey along this portion of Shoal Creek which has been highly developed.

Though a portion of the Lamar Street Dump Site (41TV137) seems to be eroding out of the creek bank north of 24th Street, the majority of the dump area is located on the hill slope above Lamar Street in the vicinity of 26th and 27th Streets. The historic site (41TV298) recorded north of U.S. Highway 183 near the Balcones Research Center appears to have been destroyed. Another historic site (41TV297) is located farther to the northwest near U.S. Highway 183 and is believed to be out of the project area.

The Seiders Oaks settlement and spring area was designated as a Texas Historic Landmark in 1967 and planning should take into account avoiding or minimizing impact from flood control channel improvements. Avoidance will be exceptionally difficult here should a channel alternative be chosen.

The significance of a final historic site, 41TV1293, was not evaluated at this time. It is a historic dump and/or homesite that is situated on the east bank of Shoal Creek just south of the 29th Street bridge. If this portion of Shoal Creek is to be impacted by the channelization project, further investigations to determine the significance of this site will be required.

No archeological sites were located during the examinations of the approximate locations of the tunnel intake structures.

1989 FIELD VISIT

In April 1989, a Corps archeologist visited the project area for several days performing surface inspection of a new location for the proposed southern tunnel outlet, and checking basic archival information on this and a new location proposed for the northern tunnel outlet. A check with staff of TARL, THC, and the Austin History Center showed no documented archeological or historical sites in the proposed tunnel outlet locations. A local historian, Mr. Brian W. Schenk, was also consulted on the southern tunnel outlet area and knew of no historical sites in the immediate location. Field inspection of the southern tunnel outlet area showed no cultural material apart from one prehistoric flake in the drainage below the railroad tracks west of West Lynn Street, and some minimal historic material including a brick and glass sherds that appear to be redeposited in the drainage. Field access to the proposed northern tunnel outlet was not possible, but a check with the apparent land owner since 1938 indicates that no prehistoric materials are commonly known to originate at that specific property. A substantial prehistoric rock shelter (41TV69) is in the vicinity across Bull Creek from the proposed

tunnel outlet, and burned rock middens have been reported upstream on Bull Creek. An 1896 USGS map depicts a historic site to be possibly about 300 to 400 meters north of the proposed northern tunnel outlet.

INFORMATION ON HISTORIC PEASE PARK

Pease Park, where the 19th Street tunnel inlet is planned, also has historical significance. A check with the Austin History Center has provided preliminary information which indicates that the park is considered to be historically important. A number of historic events or persons are associated with the park. The following information comes from several newspaper articles provided by the Austin History Center. First, on May 20, 1875, the family of Texas Governor Elisha Marshall Pease (governor from 1853 to 1857) donated 23 acres here to be used as a park by the city of Austin. Although park features were not much developed until 1926, this act makes the park among the oldest if not the first recreational park of Austin. Between approximately 1875 and 1885, at least portions of the park site were substantially used as a dumping ground by city residents. Shortly after the Civil War, General George A. Custer and 200 federal soldiers camped here, where 35 men died from fever and were buried near Shoal Creek. The remains of the 35 men were impacted by a flood in the 1890's and as a result the remnant of these burials was relocated to Arlington National Cemetery in Washington, D.C.

Also in the 1890's, a persistent rumor of lost treasure, $100,000 in Mexican gold bars "buried below the old Neal Place," prompted some of Austin's leading citizens to organize a stock company to search the park. Excavations were made, including trenches and "a hole that would reach to China" .... "under a huge rock in the middle of the stream [Shoal Creek]." The Travis County treasurer committed suicide apparently in association with his use of public money to support this treasure hunting. Many various gatherings and ceremonies were held in Pease Park, with construction of a grandstand and pavilion around 1930. Early regular events included Volunteer Fire Department celebrations held each San Jacinto Day. For example, on April 21, 1903, Austin's Mayor A.P. Wooldridge made an eloquent speech praising the park's significance. A Texas Historical Marker was dedicated at the park in April 1971. The marker is located at the end of Parkway Street, off West 12th Street.

SUMMARY OF CULTURAL RESOURCES TO DATE

Of the historic and prehistoric sites and properties presently known within the Shoal Creek project area, those listed below are of special concern.

Seiders Oaks - A pre-1850 site of an historic settlement and indian massacre, now a Texas Historic Landmark, located on the west side of Shoal Creek at 35th Street. This site includes several varieties of native Texas oaks that date to the historic settlement which is situated along an

old wagon trail, now the hike and bike trail. Intact subsurface deposits are likely and should be avoided by any construction.

Seiders Springs - Two springs used by Fort Austin and other army camps for water between 1847 and 1865. The Seiders family operated a popular resort at the springs until 1896. Intact subsurface deposits are likely. There is no proposed construction in this area.

Franz Fiset Dam - Located on Shoal Creek just below 49th Street. This historic rock dam will not be impacted by construction.

41TV1293 - A scatter of historic debris on the east bank of Shoal Creek just south of 29th Street which may represent a trash dump and/or a homesite. There is no proposed construction in this area.

Pease Park - There are no known cultural resource materials in the specific location of the 19th Street tunnel inlet. However, a general historical significance exists for the property as a whole, and further study is needed to determine impacts of the proposed construction of the NED plan. However, a general historical significance exists for the property as a whole, and further study is needed to determine the impacts of the proposed construction.

OBJECTIVES REMAINING

Several objectives remain to be accomplished before the cultural resources aspect of the proposed project are completed. In general, it may be stated that at this time there do not appear to be numerous, highly significant cultural resources which cannot be avoided or otherwise adequately treated under preservation law.

The identification level studies remain incomplete at the proposed tunnel outlet locations. Access for field inspection is required for the northern tunnel location, and the southern tunnel location should be revisited to investigate the area immediately south of that examined in April 1989, because the southern tunnel outlet has been most recently proposed to exit below the area between and below Orchard and Pressler Streets, rather than West Lynn Street. Identification level studies also remain incomplete in terms of studying the precise location for the 19th Street tunnel inlet within Pease Park. Also to be addressed is an assessment of the project's impact on Pease Park as an historically significant property. As flood control plans are refined, preservation laws require continued coordination with the State Historic Preservation Officer.

Refinement of the undertaking's description will be required in considering impacts related to construction. The location for deposition of the large volume of tunnel spoils or other excess material, even if sub-contracted out to be placed on various private lands, must undergo the same procedure of cultural resource identification and treatment as that of the primary impact areas. This action is required under Federal

preservation law. A Corps archeologist has conducted a preliminary reconnaissance of disposal sites which have been identified by the city of Austin to verify that several locations without cultural resources exist in the area. These sites located on the southeastern side of Austin are either fully permitted for receiving such material, or are suited for permitting. No cultural resources were observed in the May 1990 site visit. Other kinds of construction impacts to be considered are construction roads and equipment storage. For example, where any historic sites may exist in the vicinity of the northern tunnel outlet, haul roads may need to be carefully routed to avoid eroding such sites. Broader areas associated with any leases required for construction must also be considered.

Following additional definition of the proposed undertaking's area of effects, and completed search for cultural resources, certain sites may require evaluation under criteria of the National Register, and mitigation if found eligible for that designation. At the present level of identification studies, which are nearly complete, it appears that no known archeological sites will be impacted by the project.

Final consultation will involve both the State Historic Preservation Officer and possibly the Advisory Council on Historic Preservation. However, an emergency discovery procedure will exist at all times during the life of the project in the event that historic or prehistoric cultural remains are encountered during construction activities. In such situations, work should cease pending inspection by a Corps archeologist. Discovery of any material associated with any kind of human activity greater than 50 years in age should trigger such reports.

The Corps coordination to date with the State Historic Preservation Officer is included in the Exhibits to the Environmental Assessment.

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APPENDIX C

HYDROLOGY

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APPENDIX C

SHOAL CREEK
AUSTIN, TEXAS

HYDROLOGY

BASIN DESCRIPTION

The city of Austin, the capital of the State of Texas, is located in south central Texas in Travis County. The Colorado River flows southeast through Austin. Shoal Creek originates just north of U.S. Highway 183 and flows south to its confluence with the Colorado River. The Shoal Creek watershed drains approximately 13.2 square miles. Watershed elevation varies from 880 feet NGVD in the upper end to 430 feet NGVD in the lower end. Most of the basin is already developed with residential and commercial developments. Delineation of the watershed is shown in plate C-1.

CLIMATOLOGY

The Austin climate is generally mild with hot summers. Snowfall is infrequent and generally insignificant from a hydrologic viewpoint. Weather statistics obtained for this area from the National Oceanic and Atmospheric Administration (NOAA) Austin climatological station follow:

	MEANS (40-YEAR AVERAGE)	EXTREMES
Rainfall (Annual).....	33.34 inches	
Maximum (1957).....		51.30 inches
Minimum (1954).....		11.42 inches
Temperature (Annual).....	68 degrees F.	
Daily Maximum (June 1980)....		109 degrees F.
Daily Minimum (Feb. 1899)....		-2 degrees F.
Relative Humidity	67 percent	

FLOOD HISTORY

United States Geological Survey (USGS) records state that the highest known flood since 1885 on Shoal Creek occurred on April 22, 1915, in which thirty to forty people drowned in Shoal Creek and Waller Creek. The September 9, 1921 flood was probably somewhat lower than the 1915 flood, but higher than any since that time. No stages are available from these floods to estimate their magnitude.

Portions of the Austin area were hit with as much as ten inches of rainfall on Memorial Day 1981. This event had a particularly devastating

effect on the residents in the Shoal Creek watershed. Several lives were lost and many homes and businesses were flooded. Table C-1 presents the maximum peak discharge for this flood at each gage location.

STREAM GAGING STATIONS

Four stream gaging stations have been established in the Shoal Creek watershed. The gages are located at Steck Avenue, Northwest Park, White Rock Drive, and 12th Street. The period of record for all gages are as follows:

GAGE LOCATION	PERIOD OF RECORD	DRAINAGE AREA (SQ.MI.)
Steck Avenue	November 1974-1983	2.79
Northwest Park	March 1975-1984	6.52
White Rock Drive	April 1975-1982	6.97
12th Street	November 1974-current year	12.3

Table C-2 presents the annual peak discharges for each gage location. Only the 12th Street gage had sufficient record to perform a frequency analysis. A frequency analysis was performed on this gage using the Flood Flow Frequency Analysis program developed by the Hydrologic Engineering Center, following the Water Resources Council Bulletin 17B and Southwestern Division guidelines. Table C-3 presents the results of the frequency analysis. Plate C-2 presents the frequency-discharge curve from the frequency analysis, the synthetic model frequency-discharge curves, the partial-duration curve, and a comparison with the USGS estimate of the frequency-discharge curve. The synthetic model curves are for 1986 urbanization conditions and for base year 1999 urbanization conditions, the year the project is expected to be in place. The USGS curve is from the 1986 report "The Effects of Urbanization on Floods in the Austin Metropolitan Area, Texas." Partial duration data for this gage is available only for the years 1985-1989.

A storm reproduction of the 24 May 1981 flood was performed to calibrate the hydrologic model. Plate C-3 presents the results of this storm reproduction. A Cp 640 value of 600 was used with hydrograph reproduction loss rates of 0.5 initial loss and 0.25 hourly loss. This plate supports the reasonableness of the adopted hydrologic parameters.

FUTURE URBANIZATION AND IMPERVIOUSNESS

The Shoal Creek watershed is almost completely urbanized. It was assumed that the watershed will be completely urbanized by 1999, the year the project is expected to be completed. Plate C-2 shows the small increase in discharge this future urbanization is expected to produce. Base year 1999 urbanization conditions were used to compute with and without project discharges used in this study.

PROPOSED PROJECT

The proposed project consists of two 14-foot diversion tunnels and channel improvements in the upper portion of Shoal Creek and on Hancock Creek.

The upstream tunnel diverts flood flows from the inlet on Shoal Creek in Northwest Park into Lake Austin near the confluence of Bull Creek. The inlet structure of this tunnel is designed to allow 1,000 cfs to pass downstream before diversion into the tunnel begins, to allow lower flows with higher concentrations of pollutants to discharge into the normal discharge point of Shoal Creek, Town Lake. The lower tunnel inlet is near 19th Street and the outlet to Town Lake is near Pressler Street. The diversion structure at the inlet of the 19th Street tunnel will allow low flows to pass downstream through a 42 inch culvert through the diversion dam.

The proposed channelization on Shoal Creek is a grass-lined channel from the Missouri-Pacific Railroad to Foster Lane. The proposed improvements on Hancock Creek consist of a concrete U-wall channel from Houston Street to Burnet Road. A 10-foot by 10-foot box culvert will be added to the existing culverts through the shopping center west of Burnet Road. A 50-foot bottom width concrete U-wall channel extends from the shopping center to just downstream of Hancock Drive where it transitions to a 25-foot bottom width grass-lined channel. The grass-lined channel transitions back to the natural channel 700 feet downstream of Hancock Drive. A detailed description of the proposed project can be found in the Hydraulic Appendix.

DETERMINATION OF PERCENT SAND

The computation of percent sand for this study area was determined by comparing the permeabilities of the major soil types in Shoal Creek with those typical of the Blackland Prairie and Cross Timber regions of the state.

The Blackland Prairie is a nearly treeless, mostly flat grassland. Most of the unurbanized areas in this region are under cultivation. Soils typical of the Blackland Prairie are clay loams and clays such as the Houston Black series. The Houston Black has a permeability less than 0.06 inches per hour and is the predominate series found in watersheds used to develop the Blackland Prairie Clay Urbanization Curves. Soils having permeabilities of less than 0.06 inches per hour have therefore been defined as having a percent sand of 0 for use with these urbanization curves.

The Cross Timbers is a wooded region adjacent to the Blackland and Grand Prairies. Soils typical of the Cross Timbers are fine sandy loams such as the Crosstell series. The Crosstell has a permeability range of 0.6 to 2.0 inches per hour and is the predominate series found in watersheds used to develop the Cross Timber Sandy Loam Urbanization Curves. Soils having permeabilities in the range of 0.6 to 2.0 inches per

hour have therefore been defined as having a percent sand of 100 for use with these urbanization curves.

Percent sand values for soil types with permeability rates between those for clay and sand soils were linearly interpolated. After the percent sand for each soil type was determined, a weighting was applied by multiplying the appropriate percent sand for each soil type by the percent of the subarea covered by that soil type. The permeability rates utilized for this study area were obtained from the SCS publication, "Soil Survey of Travis County Texas", Estimated Soil Properties Significant in Engineering, table 3, pages 66-75, dated June 1974.

DETERMINATION OF URBANIZATION AND IMPERVIOUSNESS

Values of percent urbanization and imperviousness were developed for each subarea. The definitions of urbanization and imperviousness follow.

Urbanization is defined as the percentage of the basin which has been developed and improved with channelization and/or a storm collection network. The only effect of urbanization is to modify Snyder's time to peak value, Tp, of the unit hydrograph.

Imperviousness is defined as an estimate of the percentage of the basin covered with impervious material and hydraulically connected to the subarea's drainage network. The only effect of imperviousness is to decrease the volume of rainfall lost through interception and infiltration.

The urbanization and imperviousness values utilized in this study are based on a 1982 aerial photo of the watershed, future land use studies by the Corps of Engineers and field investigations.

DEVELOPMENT OF DISCHARGE-FREQUENCY RELATIONSHIPS

Rainfall for the 99.99, 50, 20, 10, 4, 2, 1, 0.2 percent chance exceedance and standard project storms was developed using data from the following documents:

National Weather Service Technical Paper 40 (TP-40),"Rainfall Frequency Atlas of the United States", dated May 1961.

NOAA Technical Memorandum NWS Hydro-35: "Five- to 60-minute Precipitation Frequency for the Eastern and Central United States", NOAA/NWS, 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 March 26, 1952.

Rainfall for the 0.2 percent chance exceedance storm was computed by extrapolation of data from the previously mentioned sources. Table C-4

summarizes the hypothetical point rainfall for Austin, Texas. The rainfall for each duration-frequency related storm was adjusted to the critical drainage area size at each discharge location based upon figure 15, Tp 40, "Depth-Area-Duration Curves". A mass rainfall curve was generated from the adjusted point rainfall values for each frequency, interpolated into incremental rainfall amounts, and distributed at 15 minute time intervals. Table C-5 presents a sample of the 1 percent chance exceedance storm distribution for a 0.54 square mile subbasin.

The Standard Project Flood was developed as outlined in EM 1110-2-1411 and distributed in time according to Southwestern Division recommendations. The 24-hour index rainfall of 16.4 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 one was used in accordance with Section 2-03B of EM 1110-2-1411. Table C-6 presents a sample of the SPF distribution for a 0.54 square mile subbasin.

Runoff volumes were computed by subtracting the applicable loss rates from the incremental rainfall amounts. Losses were deducted using the block and uniform loss method. The initial and hourly loss rates were adjusted to approximately match the synthetic model frequency-discharge curve with the computed frequency-discharge curve presented on plate C-2. The adopted loss rates are presented in table C-7.

After the runoff was computed, Snyder's unit hydrographs were developed for each subarea in the study. The unit hydrograph Tp value was derived for each subarea using methodology described in the following 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 sand and clay urbanization curves for the Crosstimber/Blackland Prairie regions of the state. These curves relate Tp to certain measurable watershed parameters for a specific percent urbanization and soil type. The pertinent data for these flood hydrograph reproductions for clay and sand watersheds are presented in tables C-8 and C-9. These curves are displayed on plates C-4 and C-5.

The urbanization curves relate Tp to the quantity L*LCA/SST**0.5 for various percent urbanizations. The definitions of these variables are:

(1) Tp - the lag time from the midpoint of the unit rainfall duration to the peak of the unit hydrograph.

(2) L - the river mileage from the discharge point to the upstream limits of the drainage area.
(3) LCA - the river mileage from the discharge point to the centroid of the drainage area.
(4) SST - the weighted river slope over the river length from 0.1*L to 0.85*L above the discharge point in feet per mile.

Based on the percentages of sand and clay, the Tp value was computed for each subbasin by interpolating between the Crosstimber/Blackland Prairie sand and clay urbanization curves. Also, a CP 640 value of 600, determined from the storm reproduction analysis, was used for this study area. The unit hydrograph data for each subbasin is presented in table C-10.

Once rainfall excesses for each frequency event and unit hydrographs were computed, multiple flood hydrographs were generated for each subarea. These hydrographs were routed using the modified Puls technique. Elevation-discharge-storage relationships used by this routing method were developed from HEC-2 backwater models. Table C-11 displays the routing data and the NUDALLAS input file for without and with project. Flood hydrographs were computed and routed for the 99.99, 50, 20, 10, 4, 2, 1, 0.2 percent chance exceedance and SPF events. The resultant peak discharges were tabulated at each point of interest.

The expected probability percent exceedance frequency relationship for each discharge location was determined by recomputing the plotting position for each computed peak discharge for without and with project based on a 40-year adjustment. The expected probability peak discharges for without and with project were interpolated from these relationships and are presented in tables C-12 and C-13. Table C-14 presents a comparison summary of the 1 percent chance exceedance event and SPF peak discharges for without and with project at various locations in the watershed.

The NUDALLAS computer program was utilized to compute the synthetic rainfall, runoff volumes, unit hydrographs, and flood hydrographs. Also, this program was used to route the flood hydrographs and tabulate the frequency peak discharges.

NORTHWEST PARK DETENTION POND MODELING CONSIDERATIONS

The city of Austin has constructed an off-channel detention pond in Northwest Park adjacent to Shoal Creek. The flood control pond at Northwest Park was designed to decrease all peaks through the 4 percent chance exceedance event, with rarer events overtopping the levee. The structure extends from Shoal Creek Boulevard to approximately 500 feet downstream of Greenlawn Parkway and is a side-weir detention pond with the inflow weir at the upstream end of the pond. The invert elevation of the inflow weir is 676.1 feet NGVD. The structure is divided into two smaller ponds. The outflow for the upper pond is a balancing channel that flows into the lower pond. The lower pond has an outflow weir invert elevation of 677.8 feet NGVD and is located at Shoal Creek Boulevard. After the

passage of the flood wave the pond empties through a 24 inch pipe with a flapgate at invert elevation 661.0 feet NGVD. Table C-15 presents the pertinent data for the detention pond. As the lower pond fills, the upper and lower pond elevations will stabilize and become a level pool. If the pool rises above the inflow weir critical elevation, outflow over the inflow weir from the pond to the creek will occur if the Shoal Creek water surface elevation is lower. Otherwise, the pond will continue to rise until the critical elevation of the outflow weir at Shoal Creek Boulevard is exceeded.

In this model, the two ponds were treated as one, requiring the assumption that the pond has a level water surface. It was assumed that once the pond reached the invert elevation of the inflow weir, Shoal Creek would be so high that no outflow would occur. And once Shoal Creek fell, the peak discharge would already have passed and the additional outflow through the inflow weir would not create a larger peak on Shoal Creek. Therefore, the only outflow condition modeled in the pond is the downstream outflow weir.

EFFECT ON LAKE LEVELS OF LAKE AUSTIN

An analysis was performed to determine the effect of the diverted flood waters from Shoal Creek on the resultant pool elevation of Lake Austin. The outlet works for Lake Austin and Tom Miller Dam has the following pertinent data:

Uncontrolled Spillway:
Length: 458 ft.
Crest Elevation: 492.8 NGVD

Controlled Spillway:
Crest Elevation: 480.8 NGVD
Control: 5 tainter gates, each 51′ by 12′
4 tainter gates, each 51′ by 18′

Normal Pool Elevation: 492.8 NGVD

The Lower Colorado River Authority (LCRA) has one employee on site at all times. Additional operational personnel are available to make gate changes based on rainfall or flow forecasts for the Colorado River. The LCRA operates the lake to keep the pool near normal pool elevation.

Of the two tunnels, only the upper tunnel at Northwest Park will divert flood flows into Lake Austin. The lower tunnel at 19th Street diverts flood flows into Town Lake, the normal discharge point of Shoal Creek.

To determine the relative effects of the Northwest Park tunnel diversions on Lake Austin elevations a hydrologic model was developed on the local Lake Austin watershed below Lake Travis. Elevation-frequency was determined on the lake for without project conditions and including Northwest Park tunnel diversions. Timing of the diverted flows is much

earlier than the mainstream Colorado River flows and no significant impact on Lake Austin peak elevations is expected. Table C-16 shows the net increase in pool elevation for Lake Austin for without and with project. Net maximum increase in pool elevation over existing conditions is approximately 0.04 feet for the SPF event. Table C-17 shows the Lake Austin pool elevation-storage-outflow relationship used to compute the increases. Table C-18 shows the total diverted discharge and volume for each design storm frequency analyzed for each tunnel.

At the request of the LCRA, a gage will be installed at the inlet of the tunnel to inform the LCRA by radio telemetry anytime the tunnel is in operation. Details of this warning system will be coordinated with the city of Austin and the LCRA.

TABLE C-1
SHOAL CREEK
OBSERVED DISCHARGES
MEMORIAL DAY 1981 STORM

GAGE LOCATION	D. A. (Sq Mi)	USGS PEAK Discharge (cfs)
Steck Avenue	2.79	5,100
Northwest Park	6.52	14,600
White Rock Drive	6.97	15,700
12th Street	12.30	16,000

TABLE C-2
SHOAL CREEK
INTERIM REPORT
ANNUAL PEAK DISCHARGES ON SHOAL CREEK

FINAL RESULTS
-PLOTTING POSITIONS- SHOAL CREEK AT WHITE ROCK DRIVE 08156750

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	MEDIAN PLOT POS
4	28	1975	1750.	1	1981	15700.	0.0833
4	18	1976	1160.	2	1982	2860.	0.2024
4	15	1977	660.	3	1979	1920.	0.3214
5	11	1978	1010.	4	1975	1750.	0.4405
7	19	1979	1920.	5	1980	1400.	0.5595
5	12	1980	1400.	6	1976	1160.	0.6786
5	24	1981	15700.	7	1978	1010.	0.7976
5	13	1982	2860.	8	1977	660.	0.9167

FINAL RESULTS
-PLOTTING POSITIONS- SHOAL CREEK AT NW.PARK 08156700

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	MEDIAN PLOT POS
4	18	1976	1060.	1	1981	14600.	0.0745
4	15	1977	580.	2	1982	2920.	0.1809
5	11	1978	978.	3	1979	2110.	0.2872
7	19	1979	2110.	4	1983	1670.	0.3936
5	12	1980	1060.	5	1980	1060.	0.5000
5	24	1981	14600.	6	1976	1060.	0.6064
5	13	1982	2920.	7	1978	978.	0.7128
8	8	1983	1670.	8	1977	580.	0.8191
7	24	1984	497.	9	1984	497.	0.9255

TABLE C-2 (CON'T)
SHOAL CREEK
INTERIM REPORT
ANNUAL PEAK DISCHARGES ON SHOAL CREEK

FINAL RESULTS
-PLOTTING POSITIONS- SHOAL CREEK AT STECK AVENUNE 08156650

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	MEDIAN PLOT POS
11	23	1974	1590.	1	1981	5100.	0.0833
4	18	1976	563.	2	1975	1590.	0.2024
4	15	1977	255.	3	1982	1240.	0.3214
5	11	1978	391.	4	1979	957.	0.4405
7	19	1979	957.	5	1980	751.	0.5595
5	12	1980	751.	6	1976	563.	0.6786
5	24	1981	5100.	7	1978	391.	0.7976
5	13	1982	1240.	8	1977	255.	0.9167

FINAL RESULTS
-PLOTTING POSITIONS- SHOAL CREEK AT 12TH ST, AUSTIN, TX 08156800

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	MEDIAN PLOT POS
11	23	1974	4800.	1	1981	16000.	.0455
4	18	1976	1670.	2	1982	7310.	.1104
4	15	1977	999.	3	1987	6870.	.1753
5	2	1978	1470.	4	1979	4970.	.2403
5	21	1979	4970.	5	1975	4800.	.3052
5	12	1980	1900.	6	1989	3950.	.3701
5	24	1981	16000.	7	1985	2940.	.4351
5	13	1982	7310.	8	1986	2850.	.5000
8	8	1983	1980.	9	1983	1980.	.5649
10	9	1983	893.	10	1980	1900.	.6299
10	20	1984	2940.	11	1988	1700.	.6948
10	19	1985	2850.	12	1976	1670.	.7597
5	29	1987	6870.	13	1978	1470.	.8247
11	25	1987	1700.	14	1977	999.	.8896
5	17	1989	3950.	15	1984	893.	.9545

TABLE C-3
SHOAL CREEK
INTERIM REPORT
FREQUENCY ANALYSIS

FINAL RESULTS
-FREQUENCY CURVE- SHOAL CREEK AT 12TH ST, AUSTIN, TX 08156800

FLOW, CFS COMPUTED	FLOW, CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS .05 LIMIT	CONFIDENCE LIMITS .95 LIMIT
29900.	51700.	.002	92200.	15900.
23300.	35000.	.005	65000.	13100.
19000.	26000.	.010	48800.	11100.
15300.	19200.	.020	35800.	9280.
10900.	12600.	.050	22500.	7060.
8150.	8900.	.100	15100.	5490.
5710.	5970.	.200	9420.	4000.
2900.	2900.	.500	4150.	2020.
1480.	1410.	.800	2110.	894.
1040.	953.	.900	1540.	561.
777.	676.	.950	1200.	378.
452.	333.	.990	771.	178.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.4632	HISTORIC EVENTS	0
STANDARD DEVIATION	.3493	HIGH OUTLIERS	0
COMPUTED SKEW	.4856	LOW OUTLIERS	0
GENERALIZED SKEW	-.4000	ZERO OR MISSING	0
ADOPTED SKEW	.0155	SYSTEMATIC EVENTS	15

TABLE C-4

SHOAL CREEK
INTERIM REPORT
HYPOTHETICAL STORM DATA IN INCHES

FREQUENCY PERCENT	YEARS	DURATION (HOURS) 0.25	0.5	1	2	3	6	12	24
99.99	1	0.87	1.03	1.32	1.92	2.10	2.44	2.84	3.21
50	2	1.10	1.57	2.05	2.34	2.60	3.06	3.52	4.11
20	5	1.27	1.90	2.55	3.11	3.43	4.11	4.90	5.59
10	10	1.40	2.14	2.91	3.65	4.02	4.89	5.80	6.72
4	25	1.60	2.49	3.42	4.30	4.72	5.79	6.85	7.92
2	50	1.76	2.77	3.82	4.80	5.33	6.47	7.79	8.91
1	100	1.91	3.04	4.22	5.39	5.98	7.25	8.76	10.12
.2	500	2.35	3.82	5.08	7.15	8.23	10.35	13.20	16.00

SPF INDEX RAINFALL = 16.4 INCHES

TABLE C-5

INDEX POINT 1 : OPTION 1 EXECUTED ON 23 SEP 89 AT 12:46:53

SHOAL CREEK
INTERIM REPORT

SHOAL CREEK * INTERIM REPORT *
1 PERCENT CHANCE STORM CENTERING ON
AREA 1-SHOAL CREEK HEADWATERS
MASS RAINFALL AND AREA REDUCTION FACTORS
DRAINAGE AREA 0.54 SQUARE MILES

DURATION	POINT RAINFALL	REDUCTION FACTOR	FINAL RAINFALL
0.25	1.8872	1.0000	1.8872
0.50	3.0419	0.9938	3.0231
1.00	4.2200	0.9966	4.2055
2.00	5.3900	0.9976	5.3773
3.00	5.9800	0.9978	5.9667
6.00	7.2500	0.9987	7.2403
12.00	8.7600	0.9987	8.7490
24.00	10.1200	0.9989	10.1089

TABLE C-5 (CONT'D)

INDEX POINT 1 : OPTION 1 EXECUTED ON 23 SEP 89 AT 12:46:54

SHOAL CREEK
INTERIM REPORT

SHOAL CREEK * INTERIM REPORT *
1 PERCENT CHANCE STORM CENTERING ON
AREA 1-SHOAL CREEK HEADWATERS
AREA 1-SHOAL CREEK HEADWATERS
DRAINAGE AREA 0.54 SQUARE MILES

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
0:15	1.	87.	0.0162	0.0045	0.0117
0:30	10.	801.	0.0165	0.0046	0.0119
0:45	15.	375.	0.0171	0.0048	0.0123
1: 0	16.	87.	0.0175	0.0049	0.0126
1:15	17.	17.	0.0182	0.0051	0.0131
1:30	18.	3.	0.0186	0.0052	0.0134
1:45	18.	1.	0.0193	0.0054	0.0139
2: 0	19.	0.	0.0197	0.0055	0.0142
2:15	19.	0.	0.0206	0.0058	0.0148
2:30	20.	0.	0.0210	0.0059	0.0151
2:45	21.	0.	0.0219	0.0061	0.0158
3: 0	21.	0.	0.0224	0.0063	0.0161
3:15	22.	0.	0.0234	0.0066	0.0169
3:30	23.	0.	0.0240	0.0067	0.0173
3:45	23.	0.	0.0251	0.0070	0.0181
4: 0	24.	0.	0.0257	0.0072	0.0185
4:15	25.	0.	0.0270	0.0076	0.0194
4:30	26.	0.	0.0276	0.0077	0.0199
4:45	27.	0.	0.0291	0.0081	0.0209
5: 0	28.	0.	0.0298	0.0083	0.0215
5:15	29.	0.	0.0314	0.0088	0.0226
5:30	30.	0.	0.0322	0.0090	0.0232
5:45	31.	0.	0.0340	0.0095	0.0245
6: 0	33.	0.	0.0349	0.0098	0.0251
6:15	34.	0.	0.0369	0.0103	0.0266
6:30	36.	0.	0.0380	0.0106	0.0274
6:45	37.	0.	0.0403	0.0113	0.0290
7: 0	39.	0.	0.0415	0.0116	0.0299
7:15	40.	0.	0.0441	0.0124	0.0318
7:30	43.	0.	0.0455	0.0127	0.0328
7:45	44.	0.	0.0485	0.0136	0.0349
8: 0	47.	0.	0.0501	0.0140	0.0361
8:15	49.	0.	0.0516	0.0145	0.0372
8:30	50.	0.	0.0521	0.0146	0.0375
8:45	51.	0.	0.0532	0.0149	0.0383

TABLE C-5 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
9: 0	52.	0.	0.0539	0.0151	0.0388
9:15	53.	0.	0.0553	0.0155	0.0398
9:30	54.	0.	0.0561	0.0157	0.0404
9:45	55.	0.	0.0579	0.0162	0.0417
10: 0	57.	0.	0.0590	0.0101	0.0488
10:15	64.	0.	0.0614	0.0084	0.0530
10:30	70.	0.	0.0628	0.0084	0.0545
10:45	74.	0.	0.0662	0.0084	0.0579
11: 0	78.	0.	0.0683	0.0084	0.0599
11:15	81.	0.	0.0731	0.0084	0.0648
11:30	86.	0.	0.0761	0.0084	0.0677
11:45	91.	0.	0.0835	0.0084	0.0751
12: 0	99.	0.	0.0881	0.0084	0.0797
12:15	107.	0.	0.0929	0.0084	0.0845
12:30	113.	0.	0.0946	0.0084	0.0862
12:45	117.	0.	0.0988	0.0084	0.0905
13: 0	122.	0.	0.1014	0.0084	0.0931
13:15	126.	0.	0.1081	0.0084	0.0997
13:30	133.	0.	0.1124	0.0084	0.1040
13:45	141.	0.	0.1238	0.0084	0.1154
14: 0	153.	0.	0.1315	0.0084	0.1232
14:15	164.	0.	0.1393	0.0084	0.1309
14:30	175.	0.	0.1454	0.0084	0.1370
14:45	190.	0.	0.2185	0.0084	0.2102
15: 0	255.	0.	0.2608	0.0084	0.2525
15:15	328.	0.	0.3791	0.0084	0.3708
15:30	455.	0.	0.4970	0.0084	0.4886
15:45	654.	0.	1.1360	0.0084	1.1276
16: 0	1286.	0.	1.8872	0.0084	1.8788
16:15	2035.	0.	0.6854	0.0084	0.6770
16:30	1380.	0.	0.3132	0.0084	0.3049
16:45	695.	0.	0.1681	0.0084	0.1597
17: 0	347.	0.	0.1368	0.0084	0.1284
17:15	216.	0.	0.1175	0.0084	0.1092
17:30	166.	0.	0.1045	0.0084	0.0961
17:45	141.	0.	0.0966	0.0084	0.0882
18: 0	126.	0.	0.0914	0.0084	0.0830
18:15	116.	0.	0.0795	0.0084	0.0712
18:30	103.	0.	0.0705	0.0084	0.0622
18:45	90.	0.	0.0644	0.0084	0.0561
19: 0	81.	0.	0.0601	0.0084	0.0517
19:15	74.	0.	0.0569	0.0084	0.0486
19:30	68.	0.	0.0545	0.0084	0.0462
19:45	65.	0.	0.0527	0.0084	0.0443
20: 0	62.	0.	0.0512	0.0084	0.0428
20:15	59.	0.	0.0470	0.0084	0.0386

TABLE C-5 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
20:30	55.	0.	0.0428	0.0084	0.0344
20:45	49.	0.	0.0391	0.0084	0.0307
21: 0	44.	0.	0.0359	0.0084	0.0275
21:15	40.	0.	0.0331	0.0084	0.0247
21:30	35.	0.	0.0306	0.0084	0.0222
21:45	32.	0.	0.0283	0.0079	0.0204
22: 0	29.	0.	0.0263	0.0074	0.0190
22:15	27.	0.	0.0245	0.0069	0.0177
22:30	25.	0.	0.0229	0.0064	0.0165
22:45	23.	0.	0.0215	0.0060	0.0155
23: 0	22.	0.	0.0201	0.0056	0.0145
23:15	20.	0.	0.0189	0.0053	0.0136
23:30	19.	0.	0.0178	0.0050	0.0128
23:45	18.	0.	0.0168	0.0047	0.0121
24: 0	17.	0.	0.0159	0.0045	0.0114
24:15	15.				
24:30	6.				
24:45	1.				
25: 0	0.				

FLOOD HYDROGRAPH VOLUME 262.89 AC-FT
RUNOFF VOLUME 267.56 AC-FT
RAINFALL 10.109 INCHES
RAINFALL LOSS 0.818 INCHES
RAINFALL EXCESS 9.290 INCHES

TABLE C-6

INDEX POINT 1 : OPTION 1 EXECUTED ON 23 SEP 89 AT 12:46:54

SHOAL CREEK
INTERIM REPORT

SHOAL CREEK * INTERIM REPORT *
SPF STORM CENTERING ON
AREA 1-SHOAL CREEK HEADWATERS
MASS RAINFALL AND AREA REDUCTION FACTORS
DRAINAGE AREA 0.54 SQUARE MILES

DURATION	POINT RAINFALL	REDUCTION FACTOR	FINAL RAINFALL
0.25	12.1739	0.2200	2.6783
0.50	12.1739	0.3300	4.0174
1.00	12.1739	0.5000	6.0870
2.00	12.1739	0.6900	8.4000
3.00	12.1739	0.8000	9.7391
6.00	19.9181	0.6112	12.1739
12.00	19.9181	0.7952	15.8388
24.00	16.4000	1.2145	19.9181
48.00	16.4000	1.3420	22.0086
72.00	16.4000	1.4261	23.3872
96.00	16.4000	1.4320	23.4846

TABLE C-6 (CONT'D)

INDEX POINT 1 : OPTION 1 EXECUTED ON 23 SEP 89 AT 12:46:54

SHOAL CREEK
INTERIM REPORT

SHOAL CREEK * INTERIM REPORT * EXISTING CONDITIONS
SPF STORM CENTERING ON
AREA 1-SHOAL CREEK HEADWATERS
AREA 1-SHOAL CREEK HEADWATERS
DRAINAGE AREA 0.54 SQUARE MILES

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
0:15	0.	87.	0.0001	0.0000	0.0001
0:30	0.	801.	0.0001	0.0000	0.0001
0:45	0.	375.	0.0001	0.0000	0.0001
1: 0	0.	87.	0.0001	0.0000	0.0001
1:15	0.	17.	0.0002	0.0000	0.0001
1:30	0.	3.	0.0002	0.0000	0.0001
1:45	0.	1.	0.0002	0.0000	0.0001
2: 0	0.	0.	0.0002	0.0000	0.0001
2:15	0.	0.	0.0002	0.0000	0.0001
2:30	0.	0.	0.0002	0.0000	0.0001
2:45	0.	0.	0.0002	0.0001	0.0001
3: 0	0.	0.	0.0002	0.0001	0.0001
3:15	0.	0.	0.0002	0.0001	0.0001
3:30	0.	0.	0.0002	0.0001	0.0001
3:45	0.	0.	0.0002	0.0001	0.0002
4: 0	0.	0.	0.0002	0.0001	0.0002
4:15	0.	0.	0.0002	0.0001	0.0002
4:30	0.	0.	0.0002	0.0001	0.0002
4:45	0.	0.	0.0002	0.0001	0.0002
5: 0	0.	0.	0.0002	0.0001	0.0002
5:15	0.	0.	0.0003	0.0001	0.0002
5:30	0.	0.	0.0003	0.0001	0.0002
5:45	0.	0.	0.0003	0.0001	0.0002
6: 0	0.	0.	0.0003	0.0001	0.0002
6:15	0.	0.	0.0003	0.0001	0.0002
6:30	0.	0.	0.0003	0.0001	0.0002
6:45	0.	0.	0.0003	0.0001	0.0002
7: 0	0.	0.	0.0003	0.0001	0.0002
7:15	0.	0.	0.0004	0.0001	0.0003
7:30	0.	0.	0.0004	0.0001	0.0003
7:45	0.	0.	0.0004	0.0001	0.0003
8: 0	0.	0.	0.0004	0.0001	0.0003
8:15	0.	0.	0.0004	0.0001	0.0003
8:30	0.	0.	0.0005	0.0001	0.0003
8:45	0.	0.	0.0005	0.0001	0.0003

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
9: 0	0.	0.	0.0005	0.0001	0.0004
9:15	0.	0.	0.0005	0.0002	0.0004
9:30	1.	0.	0.0006	0.0002	0.0004
9:45	1.	0.	0.0006	0.0002	0.0004
10: 0	1.	0.	0.0006	0.0002	0.0005
10:15	1.	0.	0.0007	0.0002	0.0005
10:30	1.	0.	0.0007	0.0002	0.0005
10:45	1.	0.	0.0008	0.0002	0.0006
11: 0	1.	0.	0.0008	0.0002	0.0006
11:15	1.	0.	0.0009	0.0002	0.0006
11:30	1.	0.	0.0009	0.0003	0.0007
11:45	1.	0.	0.0010	0.0003	0.0007
12: 0	1.	0.	0.0011	0.0003	0.0008
12:15	1.	0.	0.0012	0.0003	0.0009
12:30	1.	0.	0.0013	0.0004	0.0009
12:45	1.	0.	0.0014	0.0004	0.0010
13: 0	1.	0.	0.0015	0.0004	0.0011
13:15	1.	0.	0.0017	0.0005	0.0012
13:30	2.	0.	0.0018	0.0005	0.0013
13:45	2.	0.	0.0021	0.0006	0.0015
14: 0	2.	0.	0.0022	0.0006	0.0016
14:15	2.	0.	0.0026	0.0007	0.0019
14:30	2.	0.	0.0028	0.0008	0.0020
14:45	3.	0.	0.0034	0.0009	0.0024
15: 0	3.	0.	0.0037	0.0010	0.0026
15:15	4.	0.	0.0045	0.0013	0.0032
15:30	4.	0.	0.0050	0.0014	0.0036
15:45	5.	0.	0.0063	0.0018	0.0046
16: 0	6.	0.	0.0072	0.0020	0.0052
16:15	7.	0.	0.0080	0.0023	0.0058
16:30	8.	0.	0.0083	0.0023	0.0060
16:45	8.	0.	0.0087	0.0024	0.0063
17: 0	8.	0.	0.0090	0.0025	0.0065
17:15	9.	0.	0.0094	0.0026	0.0068
17:30	9.	0.	0.0096	0.0027	0.0069
17:45	9.	0.	0.0100	0.0028	0.0072
18: 0	10.	0.	0.0102	0.0029	0.0073
18:15	10.	0.	0.0106	0.0030	0.0076
18:30	10.	0.	0.0108	0.0030	0.0077
18:45	11.	0.	0.0111	0.0031	0.0080
19: 0	11.	0.	0.0113	0.0032	0.0081
19:15	11.	0.	0.0116	0.0032	0.0083
19:30	11.	0.	0.0118	0.0033	0.0085
19:45	12.	0.	0.0121	0.0034	0.0087
20: 0	12.	0.	0.0122	0.0034	0.0088
20:15	12.	0.	0.0125	0.0035	0.0090

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
20:30	12.	0.	0.0126	0.0035	0.0091
20:45	12.	0.	0.0129	0.0036	0.0093
21: 0	13.	0.	0.0130	0.0036	0.0094
21:15	13.	0.	0.0133	0.0037	0.0096
21:30	13.	0.	0.0134	0.0038	0.0097
21:45	13.	0.	0.0136	0.0038	0.0098
22: 0	13.	0.	0.0138	0.0039	0.0099
22:15	14.	0.	0.0140	0.0039	0.0101
22:30	14.	0.	0.0141	0.0039	0.0102
22:45	14.	0.	0.0143	0.0040	0.0103
23: 0	14.	0.	0.0144	0.0040	0.0104
23:15	14.	0.	0.0146	0.0041	0.0105
23:30	14.	0.	0.0147	0.0041	0.0106
23:45	14.	0.	0.0149	0.0042	0.0107
24: 0	15.	0.	0.0150	0.0042	0.0108
24:15	15.	0.	0.0152	0.0043	0.0109
24:30	15.	0.	0.0153	0.0043	0.0110
24:45	15.	0.	0.0154	0.0043	0.0111
25: 0	15.	0.	0.0155	0.0043	0.0112
25:15	15.	0.	0.0157	0.0044	0.0113
25:30	15.	0.	0.0158	0.0044	0.0113
25:45	16.	0.	0.0159	0.0045	0.0115
26: 0	16.	0.	0.0160	0.0045	0.0115
26:15	16.	0.	0.0161	0.0045	0.0116
26:30	16.	0.	0.0162	0.0045	0.0117
26:45	16.	0.	0.0164	0.0046	0.0118
27: 0	16.	0.	0.0164	0.0046	0.0118
27:15	16.	0.	0.0166	0.0046	0.0119
27:30	16.	0.	0.0166	0.0047	0.0120
27:45	16.	0.	0.0167	0.0047	0.0121
28: 0	16.	0.	0.0168	0.0047	0.0121
28:15	17.	0.	0.0169	0.0047	0.0122
28:30	17.	0.	0.0170	0.0048	0.0122
28:45	17.	0.	0.0171	0.0048	0.0123
29: 0	17.	0.	0.0172	0.0048	0.0124
29:15	17.	0.	0.0173	0.0048	0.0124
29:30	17.	0.	0.0173	0.0048	0.0125
29:45	17.	0.	0.0174	0.0049	0.0125
30: 0	17.	0.	0.0175	0.0049	0.0126
30:15	17.	0.	0.0176	0.0049	0.0127
30:30	17.	0.	0.0176	0.0049	0.0127
30:45	17.	0.	0.0177	0.0050	0.0128
31: 0	17.	0.	0.0178	0.0050	0.0128
31:15	18.	0.	0.0179	0.0050	0.0129
31:30	18.	0.	0.0179	0.0050	0.0129
31:45	18.	0.	0.0180	0.0050	0.0130

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
32: 0	18.	0.	0.0180	0.0051	0.0130
32:15	18.	0.	0.0181	0.0051	0.0130
32:30	18.	0.	0.0181	0.0051	0.0130
32:45	18.	0.	0.0181	0.0051	0.0130
33: 0	18.	0.	0.0181	0.0051	0.0130
33:15	18.	0.	0.0181	0.0051	0.0130
33:30	18.	0.	0.0181	0.0051	0.0131
33:45	18.	0.	0.0181	0.0051	0.0131
34: 0	18.	0.	0.0182	0.0051	0.0131
34:15	18.	0.	0.0182	0.0051	0.0131
34:30	18.	0.	0.0182	0.0051	0.0131
34:45	18.	0.	0.0182	0.0051	0.0131
35: 0	18.	0.	0.0182	0.0051	0.0131
35:15	18.	0.	0.0182	0.0051	0.0131
35:30	18.	0.	0.0183	0.0051	0.0131
35:45	18.	0.	0.0183	0.0051	0.0132
36: 0	18.	0.	0.0183	0.0051	0.0132
36:15	18.	0.	0.0183	0.0051	0.0132
36:30	18.	0.	0.0184	0.0051	0.0132
36:45	18.	0.	0.0184	0.0051	0.0132
37: 0	18.	0.	0.0184	0.0052	0.0133
37:15	18.	0.	0.0184	0.0052	0.0133
37:30	18.	0.	0.0185	0.0052	0.0133
37:45	18.	0.	0.0185	0.0052	0.0133
38: 0	18.	0.	0.0185	0.0052	0.0133
38:15	18.	0.	0.0186	0.0052	0.0134
38:30	18.	0.	0.0186	0.0052	0.0134
38:45	18.	0.	0.0187	0.0052	0.0134
39: 0	18.	0.	0.0187	0.0052	0.0135
39:15	18.	0.	0.0188	0.0053	0.0135
39:30	18.	0.	0.0188	0.0053	0.0135
39:45	19.	0.	0.0189	0.0053	0.0136
40: 0	19.	0.	0.0189	0.0053	0.0136
40:15	19.	0.	0.0190	0.0053	0.0137
40:30	19.	0.	0.0191	0.0053	0.0137
40:45	19.	0.	0.0192	0.0054	0.0138
41: 0	19.	0.	0.0192	0.0054	0.0138
41:15	19.	0.	0.0193	0.0054	0.0139
41:30	19.	0.	0.0194	0.0054	0.0140
41:45	19.	0.	0.0196	0.0055	0.0141
42: 0	19.	0.	0.0196	0.0055	0.0141
42:15	19.	0.	0.0198	0.0056	0.0143
42:30	19.	0.	0.0199	0.0056	0.0144
42:45	20.	0.	0.0201	0.0056	0.0146
43: 0	20.	0.	0.0203	0.0056	0.0147
43:15	20.	0.	0.0206	0.0056	0.0150

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
43:30	20.	0.	0.0207	0.0056	0.0151
43:45	21.	0.	0.0211	0.0056	0.0155
44: 0	21.	0.	0.0213	0.0056	0.0157
44:15	21.	0.	0.0217	0.0056	0.0161
44:30	22.	0.	0.0220	0.0056	0.0164
44:45	22.	0.	0.0226	0.0056	0.0170
45: 0	23.	0.	0.0229	0.0056	0.0174
45:15	24.	0.	0.0238	0.0056	0.0182
45:30	25.	0.	0.0243	0.0056	0.0187
45:45	25.	0.	0.0255	0.0056	0.0199
46: 0	27.	0.	0.0262	0.0056	0.0206
46:15	28.	0.	0.0280	0.0056	0.0224
46:30	30.	0.	0.0291	0.0056	0.0235
46:45	32.	0.	0.0319	0.0056	0.0263
47: 0	35.	0.	0.0337	0.0056	0.0281
47:15	38.	0.	0.0385	0.0056	0.0330
47:30	43.	0.	0.0418	0.0056	0.0363
47:45	48.	0.	0.0513	0.0056	0.0457
48: 0	58.	0.	0.0583	0.0056	0.0527
48:15	68.	0.	0.0632	0.0056	0.0577
48:30	76.	0.	0.0638	0.0056	0.0582
48:45	79.	0.	0.0649	0.0056	0.0593
49: 0	81.	0.	0.0655	0.0056	0.0599
49:15	82.	0.	0.0667	0.0056	0.0611
49:30	83.	0.	0.0673	0.0056	0.0618
49:45	84.	0.	0.0687	0.0056	0.0631
50: 0	86.	0.	0.0694	0.0056	0.0638
50:15	87.	0.	0.0709	0.0056	0.0653
50:30	89.	0.	0.0717	0.0056	0.0661
50:45	90.	0.	0.0733	0.0056	0.0677
51: 0	92.	0.	0.0742	0.0056	0.0686
51:15	93.	0.	0.0760	0.0056	0.0704
51:30	95.	0.	0.0769	0.0056	0.0714
51:45	97.	0.	0.0790	0.0056	0.0734
52: 0	99.	0.	0.0800	0.0056	0.0745
52:15	101.	0.	0.0823	0.0056	0.0767
52:30	104.	0.	0.0835	0.0056	0.0779
52:45	106.	0.	0.0860	0.0056	0.0805
53: 0	109.	0.	0.0874	0.0056	0.0818
53:15	111.	0.	0.0902	0.0056	0.0847
53:30	115.	0.	0.0918	0.0056	0.0862
53:45	117.	0.	0.0950	0.0056	0.0894
54: 0	121.	0.	0.0968	0.0056	0.0912
54:15	124.	0.	0.1005	0.0056	0.0949
54:30	128.	0.	0.1024	0.0056	0.0969
54:45	132.	0.	0.1067	0.0056	0.1011

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
55: 0	136.	0.	0.1090	0.0056	0.1034
55:15	140.	0.	0.1139	0.0056	0.1083
55:30	146.	0.	0.1165	0.0056	0.1109
55:45	151.	0.	0.1222	0.0056	0.1167
56: 0	157.	0.	0.1253	0.0056	0.1197
56:15	162.	0.	0.1296	0.0056	0.1240
56:30	168.	0.	0.1315	0.0056	0.1259
56:45	171.	0.	0.1353	0.0056	0.1297
57: 0	176.	0.	0.1373	0.0056	0.1317
57:15	179.	0.	0.1414	0.0056	0.1358
57:30	184.	0.	0.1435	0.0056	0.1379
57:45	188.	0.	0.1479	0.0056	0.1423
58: 0	193.	0.	0.1502	0.0056	0.1446
58:15	197.	0.	0.1549	0.0056	0.1493
58:30	202.	0.	0.1574	0.0056	0.1518
58:45	207.	0.	0.1625	0.0056	0.1569
59: 0	212.	0.	0.1651	0.0056	0.1595
59:15	217.	0.	0.1706	0.0056	0.1650
59:30	223.	0.	0.1734	0.0056	0.1679
59:45	228.	0.	0.1794	0.0056	0.1738
60: 0	235.	0.	0.1824	0.0056	0.1769
60:15	240.	0.	0.1852	0.0056	0.1797
60:30	244.	0.	0.1863	0.0056	0.1807
60:45	247.	0.	0.1894	0.0056	0.1838
61: 0	250.	0.	0.1917	0.0056	0.1861
61:15	254.	0.	0.1992	0.0056	0.1936
61:30	262.	0.	0.2056	0.0056	0.2000
61:45	272.	0.	0.2320	0.0056	0.2265
62: 0	299.	0.	0.2630	0.0056	0.2574
62:15	339.	0.	0.3160	0.0056	0.3104
62:30	398.	0.	0.3439	0.0056	0.3383
62:45	453.	0.	0.4482	0.0056	0.4426
63: 0	559.	0.	0.5303	0.0056	0.5247
63:15	683.	0.	0.7155	0.0056	0.7099
63:30	891.	0.	0.9317	0.0056	0.9261
63:45	1178.	0.	1.3391	0.0056	1.3336
64: 0	1719.	0.	2.6783	0.0056	2.6727
64:15	2832.	0.	1.1379	0.0056	1.1323
64:30	2095.	0.	0.6191	0.0056	0.6136
64:45	1206.	0.	0.3836	0.0056	0.3781
65: 0	705.	0.	0.2957	0.0056	0.2901
65:15	473.	0.	0.2155	0.0056	0.2099
65:30	341.	0.	0.1948	0.0056	0.1893
65:45	280.	0.	0.1877	0.0056	0.1821
66: 0	257.	0.	0.1844	0.0056	0.1788
66:15	247.	0.	0.1763	0.0056	0.1708

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
66:30	238.	0.	0.1678	0.0056	0.1622
66:45	227.	0.	0.1599	0.0056	0.1543
67: 0	216.	0.	0.1525	0.0056	0.1469
67:15	205.	0.	0.1457	0.0056	0.1401
67:30	196.	0.	0.1393	0.0056	0.1337
67:45	187.	0.	0.1334	0.0056	0.1278
68: 0	178.	0.	0.1278	0.0056	0.1222
68:15	170.	0.	0.1193	0.0056	0.1137
68:30	160.	0.	0.1114	0.0056	0.1058
68:45	149.	0.	0.1045	0.0056	0.0989
69: 0	139.	0.	0.0986	0.0056	0.0930
69:15	131.	0.	0.0934	0.0056	0.0878
69:30	123.	0.	0.0888	0.0056	0.0832
69:45	117.	0.	0.0847	0.0056	0.0792
70: 0	111.	0.	0.0811	0.0056	0.0756
70:15	105.	0.	0.0779	0.0056	0.0724
70:30	101.	0.	0.0750	0.0056	0.0695
70:45	97.	0.	0.0725	0.0056	0.0669
71: 0	93.	0.	0.0701	0.0056	0.0645
71:15	90.	0.	0.0680	0.0056	0.0624
71:30	87.	0.	0.0661	0.0056	0.0605
71:45	84.	0.	0.0643	0.0056	0.0587
72: 0	81.	0.	0.0627	0.0056	0.0571
72:15	78.	0.	0.0460	0.0056	0.0404
72:30	63.	0.	0.0359	0.0056	0.0303
72:45	48.	0.	0.0304	0.0056	0.0248
73: 0	38.	0.	0.0270	0.0056	0.0214
73:15	32.	0.	0.0248	0.0056	0.0193
73:30	28.	0.	0.0233	0.0056	0.0178
73:45	25.	0.	0.0223	0.0056	0.0167
74: 0	24.	0.	0.0215	0.0056	0.0159
74:15	22.	0.	0.0209	0.0056	0.0153
74:30	21.	0.	0.0204	0.0056	0.0148
74:45	21.	0.	0.0200	0.0056	0.0145
75: 0	20.	0.	0.0197	0.0055	0.0142
75:15	20.	0.	0.0195	0.0055	0.0140
75:30	19.	0.	0.0193	0.0054	0.0139
75:45	19.	0.	0.0191	0.0054	0.0138
76: 0	19.	0.	0.0190	0.0053	0.0137
76:15	19.	0.	0.0188	0.0053	0.0136
76:30	19.	0.	0.0187	0.0052	0.0135
76:45	19.	0.	0.0186	0.0052	0.0134
77: 0	18.	0.	0.0186	0.0052	0.0134
77:15	18.	0.	0.0185	0.0052	0.0133
77:30	18.	0.	0.0184	0.0052	0.0133
77:45	18.	0.	0.0184	0.0051	0.0132

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
78: 0	18.	0.	0.0183	0.0051	0.0132
78:15	18.	0.	0.0183	0.0051	0.0132
78:30	18.	0.	0.0182	0.0051	0.0131
78:45	18.	0.	0.0182	0.0051	0.0131
79: 0	18.	0.	0.0182	0.0051	0.0131
79:15	18.	0.	0.0181	0.0051	0.0131
79:30	18.	0.	0.0181	0.0051	0.0130
79:45	18.	0.	0.0181	0.0051	0.0130
80: 0	18.	0.	0.0181	0.0051	0.0130
80:15	18.	0.	0.0180	0.0050	0.0129
80:30	18.	0.	0.0178	0.0050	0.0128
80:45	18.	0.	0.0177	0.0049	0.0127
81: 0	17.	0.	0.0175	0.0049	0.0126
81:15	17.	0.	0.0174	0.0049	0.0125
81:30	17.	0.	0.0172	0.0048	0.0124
81:45	17.	0.	0.0170	0.0048	0.0123
82: 0	17.	0.	0.0169	0.0047	0.0121
82:15	17.	0.	0.0167	0.0047	0.0120
82:30	17.	0.	0.0165	0.0046	0.0119
82:45	16.	0.	0.0163	0.0046	0.0117
83: 0	16.	0.	0.0161	0.0045	0.0116
83:15	16.	0.	0.0158	0.0044	0.0114
83:30	16.	0.	0.0156	0.0044	0.0112
83:45	15.	0.	0.0154	0.0043	0.0111
84: 0	15.	0.	0.0151	0.0042	0.0109
84:15	15.	0.	0.0148	0.0041	0.0107
84:30	15.	0.	0.0145	0.0041	0.0105
84:45	14.	0.	0.0142	0.0040	0.0102
85: 0	14.	0.	0.0139	0.0039	0.0100
85:15	14.	0.	0.0135	0.0038	0.0097
85:30	13.	0.	0.0132	0.0037	0.0095
85:45	13.	0.	0.0128	0.0036	0.0092
86: 0	13.	0.	0.0124	0.0035	0.0089
86:15	12.	0.	0.0119	0.0033	0.0086
86:30	12.	0.	0.0114	0.0032	0.0082
86:45	11.	0.	0.0109	0.0031	0.0079
87: 0	11.	0.	0.0104	0.0029	0.0075
87:15	10.	0.	0.0098	0.0027	0.0071
87:30	10.	0.	0.0092	0.0026	0.0066
87:45	9.	0.	0.0085	0.0024	0.0061
88: 0	9.	0.	0.0078	0.0022	0.0056
88:15	8.	0.	0.0056	0.0016	0.0040
88:30	6.	0.	0.0041	0.0011	0.0029
88:45	5.	0.	0.0031	0.0009	0.0022
89: 0	3.	0.	0.0024	0.0007	0.0017
89:15	3.	0.	0.0019	0.0005	0.0014

TABLE C-6 (CONT'D)

	HYDROGRAPHS-CFS		RAINFALL CURVES-INCHES		
HOUR	FLOOD	UNIT	RAIN	LOSS	EXCESS
89:30	2.	0.	0.0016	0.0004	0.0011
89:45	2.	0.	0.0013	0.0004	0.0010
90: 0	1.	0.	0.0011	0.0003	0.0008
90:15	1.	0.	0.0010	0.0003	0.0007
90:30	1.	0.	0.0008	0.0002	0.0006
90:45	1.	0.	0.0007	0.0002	0.0005
91: 0	1.	0.	0.0007	0.0002	0.0005
91:15	1.	0.	0.0006	0.0002	0.0004
91:30	1.	0.	0.0005	0.0001	0.0004
91:45	1.	0.	0.0005	0.0001	0.0003
92: 0	0.	0.	0.0004	0.0001	0.0003

FLOOD HYDROGRAPH VOLUME 623.21 AC-FT
RUNOFF VOLUME 634.30 AC-FT
RAINFALL 23.485 INCHES
RAINFALL LOSS 1.460 INCHES
RAINFALL EXCESS 22.024 INCHES

TABLE C-7

SHOAL CREEK
INTERIM REPORT

LOSS RATES

	% CHANCE EXCEEDENCE	INITIAL LOSS (INCHES)	INFILTRATION (INCHES/HOUR)
CLAY			
	99.99	1.40	0.30
	50	1.40	0.30
	20	1.30	0.25
	10	1.12	0.20
	4	0.95	0.16
	2	0.84	0.12
	1	0.75	0.08
	0.2	0.50	0.04
	SPF	0.50	0.04
SAND			
	99.99	4.25	0.50
	50	4.25	0.50
	20	4.00	0.45
	10	3.50	0.35
	4	3.00	0.30
	2	2.20	0.22
	1	1.60	0.14
	0.2	1.00	0.10
	SPF	1.00	0.10

TABLE C-8

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED IN DEVELOPING THE BLACKLAND PRAIRIE CLAY URBANIZATION CURVES

Gage location	DA (sq mi)	Average rain (inches)	Direct runoff (inches)	Observed Peak (c.f.s)	Cp640	tp	Date	$LLca/\bar{S}^{0.5}$	% urban
White Rock Creek at Keller Springs Road	29.4	3.39	1.49	8,300	590	2.77	6 May 69	27.6	4
		1.97	0.84	4,420	612	3.5	29-30 Jun 62	27.6	0
		5.84	2.50	9,410	686	3.5	27 Jul 62	27.6	0
		1.77	0.77	3,460	423	2.5	27 Sep 64	27.6	0
		2.35	0.90	3,170	605	3.5	18 Nov 64	27.6	0
		1.75	0.65	4,560	868	3.5	27-28 May 64	27.6	0
		2.52	1.43	9,020	763	3.5	28 Apr 66	27.6	0
				Average	650	3.25			1
White Rock Creek at Greenville Avenue	66.4	3.93	1.65	24,500	620	2.5	8 Oct 62	78.4	10
		1.56	0.70	6,940	759	4.5	27 Sep 64	78.4	10
		1.96	1.00	7,500	626	4.5	18 Nov 64	78.4	10
		3.37	2.44	11,000	616	5.5	8-9 Feb 65	78.4	10
		2.64	1.77	13,800	469	3.5	10-11 May 65	78.4	10
				Average	618	4.1			10
Turtle Creek at Dallas, Texas	7.98	1.73	0.64	3,050	439	0.75	30 Apr 62	2.9	100
		4.36	2.18	4,640	338	0.75	27 Jul 62	2.9	100
		3.80	1.68	3,450	291	0.75	8 Oct 62	2.9	100
		2.82	1.81	4,290	479	0.75	28 Apr 63	2.9	100
		2.12	1.66	4,520	489	0.75	19 May 65	2.9	100
		3.55	3.04	12,200	658	0.75	28 Apr 66	2.9	100
				Average	449	0.75			100
Bachman Branch at Midway Road	10.0	5.35	3.21	9,200	255	0.75	8 Oct 62	2.6	
		4.10	1.28	3,620	468	1.25	20-21 Sep 64	2.6	
		1.10	0.69	2,910	337	0.75	21 Sep 64	2.6	
		1.36	0.58	3,050	195	0.25	22 Sep 64	2.6	
		2.36	1.52	5,170	595	1.25	10 May 65	2.6	
				Average	370	0.85			70

TABLE C-8 (CON'T)

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED IN DEVELOPING THE BLACKLAND PRAIRIE CLAY URBANIZATION CURVES

Gage location	DA (sq mi)	Average rain (inches)	Direct runoff (inches)	Observed Peak (c.f.s)	Cp640	tp	Date	$LLca/\bar{S}^{0.5}$	% urban
Joes Creek at State Highway 114	7.51	4.77	3.71	6,350	316	1.25	28 Apr 66	2.9	55
		4.64	3.28	7,300	380	0.58	8 Oct 62	2.9	50
				Average	348	0.92		2.9	53
Duck Creek at Garland, Texas (Beltline Road)	31.6	4.38	3.52	10,500	550	3.83	6 May 69	23.5	37
		3.56	1.99	7,400	388	2.5	26 Apr 58	23.5	37
		0.77	0.64	2,140	364	3.5	28-29 Apr 58	23.5	
		3.05	1.09	4,160	358	2.5	1 Oct 59	23.5	
		7.00	4.54	16,000	395	2.5	27 Jul 62	23.5	
		3.02	1.63	7,400	530	2.5	28 Apr 63	23.5	
		3.53	1.78	5,620	497	3.5	9 Feb 65	23.5	
		3.91	2.72	9,500	325	2.5	28 Apr 66	23.5	
		2.46	1.81	8,600	395	2.5	29 Apr 66	23.5	
				Average	422	2.87		23.5	35
Big Fossil Creek at Haltom City	53.8	6.15	3.73	27,200	590	3.63	7 Sep 62	47.6	5
		4.43	2.69	7,770	420	4.5	25-26 Apr 57	47.6	5
		5.86	4.62	13,000E	420	4.5	25-26 May 57	47.6	5
		6.54	2.06	18,300	603	3.5	24-25 Jun 61	47.6	5
		5.29	1.69	12,600	462	3.5	30 Sep-1 Oct 59	47.6	5
				Average	499	3.93		47.6	5
Village Creek at Handley	130.00	1.54	0.50	4,180	460	5.2	19 May 26	95.6	
		3.41	0.85	9,400	460	5.2	1 Oct 27	95.6	
		3.46	1.38	14,800	460	5.2	17 Dec 28	95.6	
				Average	460	5.2		95.6	0
Duck Creek at Buckingham Road	7.90	2.50	0.90	2,500	250	0.64	30 May 70	5.32	40
		3.17	1.79	3,960	280	0.89	16 Sep 74	5.32	60
				Average	265	0.77		5.32	50

TABLE C-8 (CON'T)

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED IN DEVELOPING THE BLACKLAND PRAIRIE CLAY URBANIZATION CURVES

Gage location	DA (sq mi)	Average rain (inches)	Direct runoff (inches)	Observed Peak (c.f.s)	Cp640	tp	Date	$LLca/\bar{S}^{0.5}$	% urban
South Mesquite Creek at Highway 352	13.4	2.89	1.86	3,420	400	1.89	23 Apr 73	6.61	65
		2.30	1.58	3,090	420	1.75	20 Sep 73	6.61	65
				Average	410	1.82			65
Marine Creek at NW 33rd Street	17.3	1.45	0.56	1,680	405	2.25	26 Apr 57	6.3	5
Sycamore Creek at I.H. 35W	17.7	1.38	0.28	1,140	450	1.77	30 May 70	7.19	18
Rowlett Creek near Sachse (Hwy 78)	120.3	3.40	2.01	24,400	600	8.36	6 May 69	112.7	4
		3.41	2.48	24,700	600	6.62	9 Dec 71	112.7	6
				Average	600	7.49			5
Five Mile Creek at Lancaster	37.9	1.85	0.70	7,040	460	1.55	30 May 70	8.44	55
		2.36	0.85	8,540	440	1.55	7 Jul 73	8.44	55
				Average	450	1.55			55
Five Mile Creek at Highway 77	13.2	3.02	1.45	6,180	300	0.49	30 May 70	5.91	55
Ten Mile Creek at Highway 342	52.8	3.74	1.86	8,820	320	2.91	3 Jun 73	24.77	25
Cedar Creek at Bonnie View Road	9.42	2.15	0.75	4,840	350	0.45	29 May 73	2.42	100
Coombs Creek at Sylvan Avenue	4.75	4.40	2.73	2,960	320	0.82	6 May 69	1.64	100

TABLE C-8 (CON'T)

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED IN DEVELOPING THE BLACKLAND PRAIRIE CLAY URBANIZATION CURVES

Gage location	DA (sq mi)	Average rain (inches)	Direct runoff (inches)	Observed Peak (c.f.s)	Cp640	tp	Date	$LLca/\bar{S}^{0.5}$	% urban
Little Fossil Creek at Mesquite Street	12.3	2.12	1.28	1,530	260	2.27	6 May 69	7.9	18
		1.61	0.83	1,370	280	1.91	30 Apr-1 May 70	7.9	18
				Average	270	2.09		7.9	18
Mountain Creek near Ceder Hill	103.5	3.38	2.35	18,500	433	5.60	25-26 Apr 70	86	1
		5.92	4.81	28,300	324	4.95	6-8 May 69	86	1
				Average	379	5.28		86	1
Honey Creek SCS Site No. 12 near McKinney	1.26	1.46	1.46	1,170	360	0.40	29 Apr 58	.216	2
		1.62	1.62	1,480	380	0.26	1 May 58	.216	2
		1.03	0.95	850	550	0.73	28 Apr 66	.216	2
		1.72	1.72	1,400	550	0.62	30 Apr 66	.216	2
				Average	460	0.50		.216	2
Honey Creek SCS Site No. 11 near McKinney	2.14	1.22	0.93	1,250	340	.50	28 Apr 66	.177	2
		2.36	2.30	3,230	320	.33	30 Apr 66	.177	2
				Average	330	.42		.177	2

TABLE C-9

PERTINENT DATA FROM REPRODUCED HYDROGRAPHS USED IN DEVELOPING
THE
CROSSTIMBER SANDY LOAM URBANIZATION CURVES

Gage location	DA (sq mi)	Average rain (inches)	Direct runoff (inches)	Initial loss (inches)	Infil-tration rate (in/hr)	Cp640	tp	Ct	Observed peak (c.f.s.)	Computed peak (c.f.s.)	% urban	L (miles)	Lca (miles)	$\bar{S}$ (ft/mi)	$LLca/\bar{S}^{0.5}$	Date	Remarks
Walnut Creek near Mansfield	62.8	3.22	1.45	.7	.13	450	7.87	1.7	4,730	4,800	1	19.72	8.38	12.6	46.5	8-10 Feb 65	90% sandy, 10% clay
		2.08	1.22	0.5	.07	550	7.87	1.7	5,390	5,200	1	19.72	8.38	12.6	46.5	30 Apr-1 May 66	
		4.70	1.67	1.4	0.2	550	7.87	1.7	6,840	6,840	1	19.72	8.38	12.6	46.5	6-7 May 69	
Rush Creek at Arkansas Lane	27.11	2.89	1.20	.6	.18	460	5.0	1.43	2,500	2,510	5	11.54	5.62	14.3	17.2	12-13 Oct 73	Personal stage observations
Big Sandy Creek near Bridgeport	333	5.00	3.15	1.75	.01	640	13.4		53,000		1				564	10-12 Jun 41	60% sandy, 40% clay
	333	4.40	1.98	1.20	.08	610	21.0		17,350		1				564	7-10 Apr 42	
				Average		625	17.2										
Big Sandy Creek near Bridgeport (Area Modified by Lake Amon Carter)	233.2	8.72	2.86	4.60	.06	400	11.3		19,110		1				202	3-6 Oct 59	80% sandy, 20% clay

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 1----------
AREA 1-SHOAL CREEK HEADWATERS

DA-SQ.MI	=	.54	L-MILE	=	1.19	LCA-MILE	= .70
SST-FT/MI	=	86.30	URBAN %	=	76.00	CP 640	= 600.00
CT	=	.38	TP-HOUR	=	.36	TPR-HOUR	= .40
QPR-CFS/MI	=	1482.39	QPR1-CFS	=	800.49	TR-HOUR	= .25
IMPERV %	=	72.00	% SAND	=	66.00		

INDEX POINT 2----------
AREA 3A-SHOAL CR ABOVE MOPAC RR

DA-SQ.MI	=	.31	L-MILE	=	.76	LCA-MILE	= .50
SST-FT/MI	=	170.20	URBAN %	=	76.00	CP 640	= 600.00
CT	=	.31	TP-HOUR	=	.23	TPR-HOUR	= .28
QPR-CFS/MI	=	2105.89	QPR1-CFS	=	652.82	TR-HOUR	= .25
IMPERV %	=	72.00	% SAND	=	66.00		

INDEX POINT 5----------
AREA 2-UT RESEARCH TRIB AT MOPAC TRIB

DA-SQ.MI	=	.36	L-MILE	=	.88	LCA-MILE	= .61
SST-FT/MI	=	59.10	URBAN %	=	76.00	CP 640	= 600.00
CT	=	.38	TP-HOUR	=	.32	TPR-HOUR	= .37
QPR-CFS/MI	=	1633.81	QPR1-CFS	=	588.17	TR-HOUR	= .25
IMPERV %	=	72.00	% SAND	=	63.00		

INDEX POINT 10----------
AREA 3-SHOAL CR ABOVE HWY 183

DA-SQ.MI	=	.38	L-MILE	=	.37	LCA-MILE	= .18
SST-FT/MI	=	25.20	URBAN %	=	76.00	CP 640	= 600.00
CT	=	.36	TP-HOUR	=	.16	TPR-HOUR	= .25
QPR-CFS/MI	=	2400.00	QPR1-CFS	=	912.00	TR-HOUR	= .25
IMPERV %	=	72.00	% SAND	=	56.00		

INDEX POINT 17----------
AREA 4-SHOAL CR ABOVE STECK AVE

DA-SQ.MI	=	.54	L-MILE	=	.87	LCA-MILE	= .45
SST-FT/MI	=	38.30	URBAN %	=	85.00	CP 640	= 600.00
CT	=	.33	TP-HOUR	=	.25	TPR-HOUR	= .30
QPR-CFS/MI	=	1997.94	QPR1-CFS	=	1078.89	TR-HOUR	= .25
IMPERV %	=	54.00	% SAND	=	40.00		

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 19----------
AREA 4A-N. BALCONES TRIB ABOVE MOPAC RR

DA-SQ.MI	=	.43	L-MILE	=	.94	LCA-MILE	= .40
SST-FT/MI	=	177.30	URBAN %	=	37.00	CP 640	= 600.00
CT	=	.39	TP-HOUR	=	.29	TPR-HOUR	= .34
QPR-CFS/MI	=	1756.50	QPR1-CFS	=	755.29	TR-HOUR	= .25
IMPERV %	=	30.00	% SAND	=	66.00		

INDEX POINT 23----------
AREA 4B-S. BALCONES TRIB ABOVE MOPAC RR

DA-SQ.MI	=	.33	L-MILE	=	1.00	LCA-MILE	= .65
SST-FT/MI	=	145.30	URBAN %	=	90.00	CP 640	= 600.00
CT	=	.31	TP-HOUR	=	.27	TPR-HOUR	= .32
QPR-CFS/MI	=	1869.20	QPR1-CFS	=	616.84	TR-HOUR	= .25
IMPERV %	=	71.00	% SAND	=	66.00		

INDEX POINT 30----------
AREA 5-SHOAL CR ABOVE FOSTER BR

DA-SQ.MI	=	.24	L-MILE	=	.57	LCA-MILE	= .31
SST-FT/MI	=	25.70	URBAN %	=	73.00	CP 640	= 600.00
CT	=	.34	TP-HOUR	=	.20	TPR-HOUR	= .26
QPR-CFS/MI	=	2336.59	QPR1-CFS	=	560.78	TR-HOUR	= .25
IMPERV %	=	52.00	% SAND	=	33.00		

INDEX POINT 33----------
AREA 6-FOSTER BR ABOVE WOODHOLLOW POND

DA-SQ.MI	=	.61	L-MILE	=	1.25	LCA-MILE	= .71
SST-FT/MI	=	131.20	URBAN %	=	86.00	CP 640	= 600.00
CT	=	.33	TP-HOUR	=	.32	TPR-HOUR	= .37
QPR-CFS/MI	=	1635.37	QPR1-CFS	=	997.58	TR-HOUR	= .25
IMPERV %	=	45.00	% SAND	=	66.00		

INDEX POINT 35----------
AREA 7-SPICEWOOD SPRINGS TRIB ABOVE SPICEWOOD SPRINGS POND

DA-SQ.MI	=	.60	L-MILE	=	1.14	LCA-MILE	= .59
SST-FT/MI	=	127.50	URBAN %	=	91.00	CP 640	= 600.00
CT	=	.31	TP-HOUR	=	.28	TPR-HOUR	= .33
QPR-CFS/MI	=	1821.47	QPR1-CFS	=	1092.88	TR-HOUR	= .25
IMPERV %	=	52.00	% SAND	=	66.00		

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 38----------
AREA 9-MOPAC POND AREA

DA-SQ.MI	=	.14	L-MILE	=	.44	LCA-MILE	= .31
SST-FT/MI	=	75.80	URBAN %	=	82.00	CP 640	= 600.00
CT	=	.31	TP-HOUR	=	.17	TPR-HOUR	= .25
QPR-CFS/MI	=	2400.00	QPR1-CFS	=	336.00	TR-HOUR	= .25
IMPERV %	=	64.00	% SAND	=	59.00		

INDEX POINT 44----------
AREA 8-FOSTER BR ABOVE SHOAL CR

DA-SQ.MI	=	.13	L-MILE	=	.62	LCA-MILE	= .43
SST-FT/MI	=	53.80	URBAN %	=	81.00	CP 640	= 600.00
CT	=	.37	TP-HOUR	=	.25	TPR-HOUR	= .30
QPR-CFS/MI	=	2018.06	QPR1-CFS	=	262.35	TR-HOUR	= .25
IMPERV %	=	41.00	% SAND	=	66.00		

INDEX POINT 48----------
AREA 10-SHOAL CR ABOVE SHOAL CREEK BLVD.(ABOVE NW. PARK)

DA-SQ.MI	=	1.52	L-MILE	=	1.53	LCA-MILE	= .93
SST-FT/MI	=	43.80	URBAN %	=	77.00	CP 640	= 600.00
CT	=	.37	TP-HOUR	=	.41	TPR-HOUR	= .45
QPR-CFS/MI	=	1322.51	QPR1-CFS	=	2010.22	TR-HOUR	= .25
IMPERV %	=	52.00	% SAND	=	37.00		

INDEX POINT 52----------
AREA 10A - NORTHWEST PARK TRIB AT NORTHWEST PARK

DA-SQ.MI	=	.26	L-MILE	=	.88	LCA-MILE	= .45
SST-FT/MI	=	75.80	URBAN %	=	74.00	CP 640	= 600.00
CT	=	.37	TP-HOUR	=	.28	TPR-HOUR	= .33
QPR-CFS/MI	=	1820.38	QPR1-CFS	=	473.30	TR-HOUR	= .25
IMPERV %	=	42.00	% SAND	=	66.00		

INDEX POINT 54----------
AREA 11-OAK HOLLOW POND TRIBUTARY HEADWATERS

DA-SQ.MI	=	.13	L-MILE	=	.66	LCA-MILE	= .27
SST-FT/MI	=	165.70	URBAN %	=	57.00	CP 640	= 600.00
CT	=	.33	TP-HOUR	=	.20	TPR-HOUR	= .25
QPR-CFS/MI	=	2396.37	QPR1-CFS	=	311.53	TR-HOUR	= .25
IMPERV %	=	54.00	% SAND	=	66.00		

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 56----------
AREA 12-OAK HOLLOW POND TRIB ABOVE SHOAL CR

DA-SQ.MI	=	.19	L-MILE	=	.33	LCA-MILE	= .27
SST-FT/MI	=	52.50	URBAN %	=	57.00	CP 640	= 600.00
CT	=	.36	TP-HOUR	=	.18	TPR-HOUR	= .25
QPR-CFS/MI	=	2400.00	QPR1-CFS	=	456.00	TR-HOUR	= .25
IMPERV %	=	54.00	% SAND	=	56.00		

INDEX POINT 61----------
AREA 13-SHOAL CR ABOVE WHITE ROCK DR

DA-SQ.MI	=	.27	L-MILE	=	.55	LCA-MILE	= .32
SST-FT/MI	=	26.70	URBAN %	=	78.00	CP 640	= 600.00
CT	=	.35	TP-HOUR	=	.21	TPR-HOUR	= .26
QPR-CFS/MI	=	2287.55	QPR1-CFS	=	617.64	TR-HOUR	= .25
IMPERV %	=	41.00	% SAND	=	43.00		

INDEX POINT 64----------
AREA 14-SHOAL CR ABOVE HANCOCK CR

DA-SQ.MI	=	1.13	L-MILE	=	1.93	LCA-MILE	= 1.03
SST-FT/MI	=	57.30	URBAN %	=	54.00	CP 640	= 600.00
CT	=	.50	TP-HOUR	=	.62	TPR-HOUR	= .65
QPR-CFS/MI	=	923.45	QPR1-CFS	=	1043.50	TR-HOUR	= .25
IMPERV %	=	30.00	% SAND	=	65.00		

INDEX POINT 67----------
AREA 15A - HANCOCK CREEK HEADWATERS ABOVE ARROYO SECA

DA-SQ.MI	=	.13	L-MILE	=	.51	LCA-MILE	= .20
SST-FT/MI	=	68.00	URBAN %	=	90.00	CP 640	= 600.00
CT	=	.31	TP-HOUR	=	.15	TPR-HOUR	= .25
QPR-CFS/MI	=	2400.00	QPR1-CFS	=	312.00	TR-HOUR	= .25
IMPERV %	=	47.00	% SAND	=	66.00		

INDEX POINT 68----------
AREA 15B - HANCOCK CREEK ABOVE PAYNE AVENUE

DA-SQ.MI	=	.22	L-MILE	=	.56	LCA-MILE	= .37
SST-FT/MI	=	66.70	URBAN %	=	78.00	CP 640	= 600.00
CT	=	.35	TP-HOUR	=	.22	TPR-HOUR	= .27
QPR-CFS/MI	=	2238.05	QPR1-CFS	=	492.37	TR-HOUR	= .25
IMPERV %	=	42.00	% SAND	=	64.00		

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 71----------
AREA 15C - HANCOCK CREEK ABOVE TRIB H-1

DA-SQ.MI	=	.33	L-MILE	=	.97	LCA-MILE	= .52
SST-FT/MI	=	27.50	URBAN %	=	90.00	CP 640	= 600.00
CT	=	.37	TP-HOUR	=	.30	TPR-HOUR	= .35
QPR-CFS/MI	=	1703.57	QPR1-CFS	=	562.18	TR-HOUR	= .25
IMPERV %	=	49.00	% SAND	=	50.00		

INDEX POINT 74----------
AREA 15D - TRIB H-1 ABOVE HANCOCK CREEK

DA-SQ.MI	=	.70	L-MILE	=	1.35	LCA-MILE	= 1.04
SST-FT/MI	=	59.30	URBAN %	=	68.00	CP 640	= 600.00
CT	=	.45	TP-HOUR	=	.49	TPR-HOUR	= .53
QPR-CFS/MI	=	1122.97	QPR1-CFS	=	786.08	TR-HOUR	= .25
IMPERV %	=	43.00	% SAND	=	66.00		

INDEX POINT 76----------
AREA 15E - HANCOCK CREEK ABOVE BURNET ROAD

DA-SQ.MI	=	.47	L-MILE	=	.92	LCA-MILE	= .57
SST-FT/MI	=	36.20	URBAN %	=	83.00	CP 640	= 600.00
CT	=	.41	TP-HOUR	=	.34	TPR-HOUR	= .39
QPR-CFS/MI	=	1551.04	QPR1-CFS	=	728.99	TR-HOUR	= .25
IMPERV %	=	45.00	% SAND	=	66.00		

INDEX POINT 79----------
AREA 15F - HANCOCK CREEK ABOVE SHOAL CREEK

DA-SQ.MI	=	.15	L-MILE	=	.51	LCA-MILE	= .39
SST-FT/MI	=	57.50	URBAN %	=	70.00	CP 640	= 600.00
CT	=	.38	TP-HOUR	=	.23	TPR-HOUR	= .28
QPR-CFS/MI	=	2111.50	QPR1-CFS	=	316.72	TR-HOUR	= .25
IMPERV %	=	44.00	% SAND	=	66.00		

INDEX POINT 83----------
AREA 16-SHOAL CR ABOVE W 34TH ST

DA-SQ.MI	=	.95	L-MILE	=	1.35	LCA-MILE	= .84
SST-FT/MI	=	24.70	URBAN %	=	68.00	CP 640	= 600.00
CT	=	.50	TP-HOUR	=	.52	TPR-HOUR	= .56
QPR-CFS/MI	=	1072.15	QPR1-CFS	=	1018.54	TR-HOUR	= .25
IMPERV %	=	40.00	% SAND	=	61.00		

TABLE C-10
SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
UNIT HYDROGRAPH DATA - OPTION 1

INDEX POINT 86----------
AREA 17-SHOAL CR ABOVE W 24TH ST

DA-SQ.MI	=	.84	L-MILE	=	1.75	LCA-MILE	= .96
SST-FT/MI	=	64.80	URBAN %	=	90.00	CP 640	= 600.00
CT	=	.38	TP-HOUR	=	.45	TPR-HOUR	= .49
QPR-CFS/MI	=	1222.18	QPR1-CFS	=	1026.63	TR-HOUR	= .25
IMPERV %	=	68.00	% SAND	=	64.00		

INDEX POINT 89----------
AREA 18-SHOAL CR ABOVE W 12TH ST

DA-SQ.MI	=	.90	L-MILE	=	1.39	LCA-MILE	= .50
SST-FT/MI	=	107.40	URBAN %	=	82.00	CP 640	= 600.00
CT	=	.34	TP-HOUR	=	.31	TPR-HOUR	= .35
QPR-CFS/MI	=	1696.41	QPR1-CFS	=	1526.77	TR-HOUR	= .25
IMPERV %	=	64.00	% SAND	=	64.00		

INDEX POINT 93----------
AREA 19-SHOAL CR ABOVE COLORADO RIVER

DA-SQ.MI	=	.40	L-MILE	=	.97	LCA-MILE	= .62
SST-FT/MI	=	41.20	URBAN %	=	88.00	CP 640	= 600.00
CT	=	.40	TP-HOUR	=	.34	TPR-HOUR	= .39
QPR-CFS/MI	=	1537.34	QPR1-CFS	=	614.93	TR-HOUR	= .25
IMPERV %	=	70.00	% SAND	=	68.00		

TABLE C-11


```
* THIS IS THE POST-LINKED FILE FROM PRELINK
* STANDARD TUNNEL SIZE IN THIS MODEL IS 14' UNLESS SPECIFIED
* ############## ############## ############## ##############
* OPTION 1 IS EXISTING CONDITIONS ROUTING DATA
* OPTION 2 IS THE IMPROVED CHANNEL OPTION
* OPTION 3 IS THE NW PARK DETENTION POND W/NO FLOW OVER INFLOW WEIR
* OPTION 5 IS THE NW PARK FACILITY W/FLOW OVER INFLOW WEIR
* OPTION 6 IS THE EXISTING CONDITIONS UNIT HYDROGRAPH DATA
* OPTION 7 - NORTHWEST PARK TUNNEL DIVERSION
* OPTION 8 - HANCOCK CREEK INTAKE FOR LOWER TUNNEL
* OPTION 9 - SHOAL CREEK INTAKE FOR LOWER TUNNEL
* OPTION 10 - ULTIMATE CONDITIONS UHG CALIBRATION RUN
* OPTION 11 - EXISTING CONDITIONS UHG CALIBRATION RUN
* OPTION 12 - RECOMMENDED PLAN
*            SHOAL & HANCOCK CREEK CHANNELIZATION, NW PARK & 19TH ST TUNNEL
* OPTION 13 - IMPROVED CHANNEL AND NW PARK POND
* OPTION 14 - IMPROVED CHANNEL, NW PARK POND, NW PARK 14' TUNNEL,
*             19TH STREET 14' TUNNEL, HANCOCK CREEK CHANNELIZATION
* OPTION 15 - EXISTING CONDITIONS W/ NW PARK POND
* OPTION 18 - MAXIMUM DESIGN CHANNEL
* OPTION 19 - 19TH STREET TUNNEL INTAKE - 18.5' DIAMETER
* OPTION 20 - LAKE AUSTIN ROUTING WITHOUT SHOAL CREEK TUNNEL DIVERSIONS
* OPTION 21 - NW PARK POND,19TH STREET TUNNEL(18.5'),1-50YR VALID
* OPTION 22 - NW PARK POND,19TH STREET TUNNEL(18.5'),100-SPF VALID
* OPTION 23 - NW PARK POND,19TH STREET TUNNEL(16'),1-50YR VALID
* OPTION 24 - NW PARK POND,19TH STREET TUNNEL(16'),100-SPF VALID
* OPTION 25 - 19TH STREET TUNNEL INTAKE - 16' DIAMETER
* OPTION 26 - NW PARK POND,19TH STREET TUNNEL(14'),1-50YR VALID
* OPTION 27 - NW PARK POND,19TH STREET TUNNEL(14'),100-SPF VALID
* OPTION 28 - 19TH STREET TUNNEL INTAKE - 14' DIAMETER
* OPTION 29 - NW PARK TUNNEL INLET - 14' DIAMETER
* OPTION 30 - IMPROVED CHANNEL, NW PARK POND, NW PARK 14' TUNNEL
*             14' TUNNEL AT 19TH STREET
* OPTION 31 - NW PARK POND AND NW PARK 14' TUNNEL ONLY
* OPTION 32 - IMPROVED CHANNEL, NW PARK POND, AND NW PARK 14' TUNNEL ONLY
* OPTION 33 - HANCOCK CREEK CHANNELIZATION
* OPTION 34 - HANCOCK CREEK CHANNELIZATION, 1-50 YR VALID
* OPTION 35 - HANCOCK CREEK CHANNELIZATION, 100-SPF VALID
* ############## ############## ############## ##############
SHOAL CREEK * FEASIBILITY STUDY * OCTOBER 1986
SKIPOPTION -1
DATA
DEBUG WRITE-UP = ON
SCHEMATIC DIAGRAM DISPLAY = ON
LOCAL PRINTOUT
8 8 8 8 8 8 8 8 8
COMBINE PRINTOUT
8 8 8 8 8 8 8 8 8
ROUTE PRINTOUT
8 8 8 8 8 8 8 8 8
```

```
*************************************************************************
OPTION 1
TITLED DATA
*SHOAL CREEK * W/O PROJECT/NWP POND FULL/100-SPF VALID
SHOAL CREEK * INTERIM REPORT * EXISTING CONDITIONS
ENDOPTION
*************************************************************************
OPTION 5
TITLED DATA
NW PARK FACILITY W/FLOW OVER INFLOW WEIR
INCLUDES-OPTIONS = 1
TR = 0.0333
ENDOPTION
*************************************************************************
OPTION 10
TITLED DATA
SHOAL CREEK * ULTIMATE CONDITIONS UHG CALIBRATION RUN * OCTOBER 1986
INCLUDES-OPTIONS = 1
ENDOPTION
*************************************************************************
OPTION 11
TITLED DATA
SHOAL CREEK * EXISTING CONDITIONS UHG CALIBRATION RUN * OCTOBER 1986
INCLUDES-OPTIONS = 1 6
ENDOPTION
*************************************************************************
OPTION 12
TITLED DATA
SHOAL CREEK * INTERIM REPORT * RECOMMENDED PLAN
INCLUDES-OPTIONS = 2 3 28 29 33
ENDOPTION
*************************************************************************
OPTION 13
TITLED DATA
SHOAL CREEK * CHANNEL OPTION & NW PARK POND
INCLUDES-OPTIONS = 2 3
ENDOPTION
*************************************************************************
OPTION 14
TITLED DATA
SHOAL CREEK * CHANNEL OPTION/NW PARK POND/NWPARK TUNNEL/19TH STREET TUNNEL
INCLUDES-OPTIONS = 2 3 7 19
ENDOPTION
*************************************************************************
OPTION 15
TITLED DATA
*SHOAL CREEK * W/O PROJECT/NWP POND EMPTY/1-50YR VALID
SHOAL CREEK * INTERIM REPORT * EXISTING CONDITIONS
INCLUDES-OPTIONS = 1 3
ENDOPTION
```

```
**********************************************************************
OPTION 16
TITLED DATA
SHOAL CREEK * CHANNEL OPTION & NW PARK POND
INCLUDES-OPTIONS = 2
ENDOPTION
**********************************************************************
OPTION 17
TITLED DATA
SHOAL CREEK * MAXIMUM CHANNEL OPTION AND NW PARK POND
INCLUDES-OPTIONS = 3 18
ENDOPTION
**********************************************************************
OPTION 20
TITLED DATA
SHOAL CREEK * LAKE AUSTIN ROUTING WITHOUT SHOAL CREEK TUNNEL DIVERSIONS
ENDOPTION
**********************************************************************
OPTION 21
TITLED DATA
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(18.5')/1-50YR VALID
INCLUDES-OPTIONS = 1 3 19
ENDOPTION
**********************************************************************
OPTION 22
TITLED DATA
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(18.5')/100-SPF VALID
INCLUDES-OPTIONS = 1 19
ENDOPTION
**********************************************************************
OPTION 23
TITLED DATA
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(16')/1-50YR VALID
INCLUDES-OPTIONS = 1 3 25
ENDOPTION
**********************************************************************
OPTION 24
TITLED DATA
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(16')/100-SPF VALID
INCLUDES-OPTIONS = 1 25
ENDOPTION
**********************************************************************
OPTION 26
TITLED DATA
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(14')/1-50YR VALID
INCLUDES-OPTIONS = 1 3 28
ENDOPTION
**********************************************************************
OPTION 27
TITLED DATA
```

```
SHOAL CREEK * NWP POND EMPTY/19TH STREET TUNNEL(14')/100-SPF VALID
INCLUDES-OPTIONS = 1 28
ENDOPTION
**********************************************************************
OPTION 30
TITLED DATA
SHOAL CREEK * CHANNEL OPTION/NW PARK POND/NWPARK TUNNEL/19TH STREET TUNNEL(
INCLUDES-OPTIONS = 2 3 29 28
ENDOPTION
**********************************************************************
OPTION 31
TITLED DATA
SHOAL CREEK * NW PARK POND/NWPARK TUNNEL(14')
INCLUDES-OPTIONS = 1 3 29
ENDOPTION
**********************************************************************
OPTION 32
TITLED DATA
SHOAL CREEK * CHANNEL OPTION/NW PARK POND/NWPARK TUNNEL(14')
INCLUDES-OPTIONS = 2 3 29
ENDOPTION
**********************************************************************
OPTION 34
TITLED DATA
SHOAL CREEK * HANCOCK CREEK CHANNELIZATION * 1-50YR VALID
INCLUDES-OPTIONS = 1 3 33
ENDOPTION
**********************************************************************
OPTION 35
TITLED DATA
SHOAL CREEK * HANCOCK CREEK CHANNELIZATION * 100-SPF VALID
INCLUDES-OPTIONS = 1 33
ENDOPTION
**********************************************************************
DATA
MODIFIED UHG DISPLAY = ON
CP 640 = 600
EXPECTED PROBABILITY DISPLAY = ON
1 YEAR RAINFALL
1.31 1.63 1.92 2.10 2.44 2.84 3.21
2 YEAR RAINFALL
1.58 2.00 2.34 2.60 3.06 3.52 4.11
5 YEAR RAINFALL
2.02 2.55 3.11 3.43 4.11 4.90 5.59
10 YEAR RAINFALL
2.35 2.95 3.65 4.02 4.89 5.80 6.72
25 YEAR RAINFALL
2.73 3.44 4.30 4.72 5.79 6.85 7.92
50 YEAR RAINFALL
3.07 3.98 4.80 5.33 6.47 7.79 8.91
```

```
100 YEAR RAINFALL
3.41 4.33 5.39 5.98 7.25 8.76 10.12
500 YEAR RAINFALL
4.10 5.75 7.15 8.23 10.35 13.20 16.00
HYDRO-35 RAINFALL
1.1 2.05 1.91 4.22
SPF RAINFALL
16.40
DATA
UHG DATA
RESET
LENGTH
LCA
SLOPE
DUMMY ARGUMENT
PERCENT SAND
DUMMY ARGUMENT
PERCENT URBANIZATION
IMPERVIOUSNESS
DATA
1ST RIL & FAV
1.400 1.400 1.300 1.120 0.950 0.840 0.750 0.500 0.500
0.300 0.300 0.250 0.200 0.160 0.120 0.080 0.040 0.040
2ND RIL & FAV
4.250 4.250 4.000 3.500 3.000 2.200 1.600 1.000 1.000
0.500 0.500 0.450 0.350 0.300 0.220 0.140 0.100 0.100
OPTION 6
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
ENDOPTION
*@@@@@@@@@@@
OPTION 20
SKIPTO OPT20
ENDOPTION
*@@@@@@@@@@@@
DATA
ROUTE INITIALIZATION DATA
DIVERSION STORAGE
ROUTE DATA TABLE
DIVERSION
AREA 1-SHOAL CREEK HEADWATERS
0.54 1.19 0.70 86.3 0 66 0 76 72
AREA 3A-SHOAL CR ABOVE MOPAC RR
0.31 0.76 0.50 170.2 0 66 0 76 72
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 3A WITH SHOAL CREEK
```

```
PRINTOUT
*
*ROUTING THRU RR CULVERT AT A-1 WITH DIVERSION TO A-3A
*
* ROUTE THROUGH AREA 3A OF SHOAL CREEK
TITLED ROUTE
SHOAL CREEK BELOW RR CULVERT AT A-1 DIVERSION
0 0 0 8 1 1
747.5 0 0 0
748 13 0 0
750 80 0.78 300
752 190 10.0 1050
754 500 33.42 2230
756 750 62.84 3650
758 1000 110.05 5225
760 1250 162.42 7025
DISPLAY POINT
AREA 2-UT RESEARCH TRIB AT MOPAC TRIB
0.36 0.88 0.61 59.1 33 63 32 76 72
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
NO PRINTOUT
TITLED CONFLUENCE
SHOAL CREEK BELOW CONFLUENCE WITH AREA 2 TRIBUTARY
*
*RESTORE DIVERTED FLOW FROM A-1
*
TITLED RESTORE
RESTORE DIVERTED FLOW FROM A-1
1
*
*ROUTE RESTORED FLOW THRU RR CULVERT AT A-3A WITH DIVERSION TO A-4A
*
ROUTE
0 0 0 7 1 2
748 0 0 0
750 250 0 50
752 850 0 200
754 1680 0 550
756 2650 0 1000
758 3525 0 1700
760 4425 0 2600
NO PRINTOUT
COMBINE
PRINTOUT
AREA 3-SHOAL CR ABOVE HWY 183
0.38 0.37 0.18 25.2 76 56 72
```

```
PRINTOUT
TITLED COMBINE
COMBINED INFLOW INTO THE HIGHWAY 183 CULVERTS
NO PRINTOUT
*
*ROUTE THRU HWY 183 CULVERT WITH DIVERSION TO A-4A
*
OPTION 1
TITLED ROUTE
*SHOAL CR THRU HWY 183 EXISTING CULVERTS
SHOAL CREEK BELOW HWY 183 CULVERTS
0 0 0 9 1 3
737.7 0 0 0
740.0 600 2.96 0
742 850 9.68 0
744 1000 37.08 0
746.0 1150 72.04 0
748 1250 130.71 100
750 1350 224.41 400
752 1400 342.99 1600
754 1500 414.10 3600
ENDOPTION
OPTION 2 18
TITLED ROUTE
* ROUTE THRU HWY 183 CULVERT (INCLUDING 2-11' CONDUITS)
SHOAL CREEK BELOW HWY 183 CULVERTS
0 0 0 11 1 3
731.5 0 0 0
735 270 0 0
737.7 700 0 0
740 1200 2.96 0
742 1720 9.68 0
744 2100 37.08 0
746 2900 72.04 0
748 3800 130.71 100
750 4850 224.41 400
752 6500 342.99 1600
754 9000 414.1 3600
ENDOPTION
DISPLAY POINT
*
*RESTORE DIVERTED FLOW FROM A-3A
*
TITLED RESTORE
RESTORE DIVERTED FLOW FROM A-3A
2
*
*RESTORE DIVERTED FLOW FROM A-3
*
TITLED RESTORE
```

```
RESTORE DIVERTED FLOW FROM A-3
3
*
*COMBINE RESTORED FLOWS
*
TITLED COMBINE
FLOWS THROUGH RR UNDERPASS ON HWY 183
RE-TITLE
SHOAL CR BELOW 183
*
*COMBINE RESTORED FLOW WITH MAIN CHANNEL FLOW
*
PRINTOUT
TITLED COMBINE
SHOAL CREEK BELOW CONFLUENCE OF RR UNDERPASS DIVERSION
DATA
UHG DATA
RESET
LENGTH
LCA
SLOPE
DUMMY ARGUMENT
PERCENT SAND
DUMMY ARGUMENT
PERCENT URBANIZATION
IMPERVIOUSNESS
OPTION 6
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
ENDOPTION
AREA 4-SHOAL CR ABOVE STECK AVE
0.54 0.87 0.45 38.3 61 40 42 85 54
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
PRINTOUT
TITLED COMBINE
SHOAL CREEK ABOVE N. BALCONES TRIBUTARY
NO PRINTOUT
AREA 4A-N. BALCONES TRIB ABOVE MOPAC RR
0.43 0.94 0.40 177.3 37 66 30
*
*ROUTING THRU RR CULVERT AT A-4A WITH DIVERSION TO A-4B
*
TITLED ROUTE
```

```
N.BALCONES TRIB BELOW MOPAC RR
0 0 0 5 1 4
732.0 0 0 0
733.0 60 0 0
736.0 540 0.03 0
738.0 1000 0.31 170
740.0 1280 2.62 440
PRINTOUT
TITLED CONFLUENCE
SHOAL CREEK BELOW CONFLUENCE WITH AREA 4A-N BALCONES TRIB
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
*
*ROUTING THRU AREA 4
*
OPTION 1
TITLED ROUTE
SHOAL CREEK ABOVE S. BALCONES TRIB. (AT STECK AVENUE)
* HEC2 INDEX 1
0 0 0 10 1
704.300 0.000 0.000
706.100 200.000 6.400
707.600 500.000 12.100
709.000 1000.000 19.900
710.600 2000.000 38.700
712.700 5000.000 140.700
718.400 10000.000 313.600
719.500 15000.000 416.900
720.200 20000.000 499.100
721.000 30000.000 629.900
DISPLAY POINT
ENDOPTION
OPTION 2
TITLED ROUTE
SHOAL CREEK ABOVE S. BALCONES TRIB. (AT STECK AVENUE)
0 0 0 10 1
702.20 0.00 0.00
703.60 200.00 5.70
704.50 500.00 10.40
705.60 1000.00 16.80
707.20 2000.00 27.30
710.10 5000.00 60.30
713.40 10000.00 177.50
718.40 15000.00 317.50
720.00 20000.00 421.70
721.20 30000.00 587.50
DISPLAY POINT
```

```
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ENDOPTION
OPTION 17
* HEC2 INDEX   1
TITLED ROUTE
SHOAL CREEK ABOVE S. BALCONES TRIB. (AT STECK AVENUE)
 0 0 0 10 1
    702.200        0.000        0.000
    703.400      200.000        6.200
    704.200      500.000       11.200
    705.200     1000.000       17.700
    706.700     2000.000       28.500
    709.500     5000.000       57.300
    712.200    10000.000      152.700
    714.900    15000.000      242.500
    719.300    20000.000      378.500
    721.000    30000.000      562.400
DISPLAY POINT
ENDOPTION
*USGS STREAM GAGING STATION AT STECK AVE
DATA
UHG DATA
RESET
LENGTH
LCA
SLOPE
DUMMY ARGUMENT
PERCENT SAND
DUMMY ARGUMENT
PERCENT URBANIZATION
IMPERVIOUSNESS
OPTION 6
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
ENDOPTION
AREA 4B-S. BALCONES TRIB ABOVE MOPAC RR
0.33 1.00 0.65 145.3 84 66 64 90 71
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
*
*RESTORE FLOW FROM A-4A
*
TITLED RESTORE
DIVERSION FROM N. BALCONES TRIB.
4
```

```
NO PRINTOUT
TITLED COMBINE
RESTORING THE N. BALCONES TRIB. DIVERSION
PRINTOUT
*
*ROUTING THRU RR CULVER AT A-4B WITH DIVERSION TO A-4
*
DATA
ROUTE INITIALIZATION DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
DEFAULT
DIVERSION
TITLED ROUTE
S. BALCONES TRIB BELOW MOPAC RR
0 0 0 5 1 5
726.0 0 0 0
734.0 1000 0.57 0
736.0 1500 2.40 0
738.0 2200 9.99 0
740.0 6500 27.20 0
PRINTOUT
TITLED CONFLUENCE
SHOAL CR. BELOW S. BALCONES TRIBUTARY
*
*RESTORE FLOW FROM A-4B
*
TITLED RESTORE
DIVERSION FROM S. BALCONES TRIBUTARY
5
PRINTOUT
DATA
PLOT FREQ = OFF
*FREQUENCY CURVE
*1M2PK*STEKPLOT
TITLED COMBINE
SHOAL CREEK BELOW CONFLUENCE OF DIVERSION FROM S. BALCONES TRIB.
DATA
PLOT FREQ = OFF
AREA 5-SHOAL CR ABOVE FOSTER BR
0.24 0.57 0.31 25.7 73 33 52
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 5 WITH SHOAL CREEK
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
```

```
OPTION 1
TITLED ROUTE
SHOAL CREEK ABOVE FOSTER BRANCH (BELOW ANDERSON LANE)
* HEC2 INDEX 2
0 0 0 10 1
685.500 0.000 0.000
687.100 200.000 4.300
688.200 500.000 7.800
689.600 1000.000 12.500
691.700 2000.000 22.800
696.800 5000.000 68.000
698.500 10000.000 147.400
700.000 15000.000 212.900
701.800 20000.000 267.700
704.200 30000.000 361.600
DISPLAY POINT
ENDOPTION
OPTION 2
TITLED ROUTE
SHOAL CREEK ABOVE FOSTER BRANCH (BELOW ANDERSON LANE)
0 0 0 10 1
683.70 0.00 0.00
684.50 200.00 3.30
685.10 500.00 6.00
686.10 1000.00 9.60
687.60 2000.00 15.40
690.80 5000.00 31.10
694.00 10000.00 70.30
696.60 15000.00 146.20
699.10 20000.00 224.10
702.40 30000.00 328.50
DISPLAY POINT
ENDOPTION
OPTION 17
* HEC2 INDEX   2
TITLED ROUTE
SHOAL CREEK ABOVE FOSTER BRANCH (BELOW ANDERSON LANE)
 0 0 0 10 1
    683.700        0.000        0.000
    684.500      200.000        3.500
    685.200      500.000        6.400
    686.100     1000.000       10.100
    687.300     2000.000       16.200
    690.000     5000.000       31.100
    693.100    10000.000       71.700
    695.500    15000.000      147.400
    698.800    20000.000      224.200
    702.700    30000.000      335.700
DISPLAY POINT
ENDOPTION
```

```
DATA
UHG DATA
RESET
LENGTH
LCA
SLOPE
DUMMY ARGUMENT
PERCENT SAND
DUMMY ARGUMENT
PERCENT URBANIZATION
IMPERVIOUSNESS
OPTION 6
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
ENDOPTION
AREA 6-FOSTER BR ABOVE WOODHOLLOW POND
0.61 1.25 0.71 131.2 77 66 40 86 45
TITLED ROUTE
FOSTER BRANCH BELOW WOOD HOLLOW POND
0 0 0 13 1
745 0 0
746 29 1.19
747 156 2.64
748 315 4.42
750 450 8.96
752 540 14.61
754 625 21.16
756 700 28.45
758 770 36.43
760 817 45.05
761 957 49.53
764 1844 63.58
767 6295 79.57
AREA 7-SPICEWOOD SPRINGS TRIB ABOVE SPICEWOOD SPRINGS POND
0.60 1.14 0.59 127.5 77 66 41 91 52
DATA
UHG DATA
DEFAULT
PERCENT SAND
IMPERVIOUSNESS
TITLED ROUTE
SPICEWOOD SPRINGS BRANCH BELOW SPICEWOOD SPRINGS POND
0 0 0 10 1
747.0 0 0
748.0 41 0
750.0 213 0.02
752.0 458 0.08
```

```
754.0 759 0.17
756.0 1106 0.35
757.4 1358 0.59
758.0 1480 0.72
758.5 1667 0.86
759.0 1927 1.04
NO PRINTOUT
TITLED CONFLUENCE
FOSTER BRANCH BELOW SPICEWOOD SPRINGS TRIB
AREA 9-MOPAC POND AREA
0.14 0.44 0.31 75.8 82 59 64
ROUTE
0 0 0 7 1
726.0 0 0
727.0 4.4 0.82
728.0 14.5 2.52
729.0 18.9 4.32
729.5 20.3 5.26
730.0 269.0 6.00
730.5 726.0 6.90
ROUTE
0 0 0 8 1
720.0 0 0
721.0 4.4 0.73
722.0 13.1 2.25
723.0 17.4 3.86
724.0 21.3 5.57
725.0 25.2 7.38
726.5 30.0 10.30
727.0 243.0 11.30
ROUTE
0 0 0 9 1
713.0 0 0
714.0 4.4 0.53
715.0 9.5 1.34
716.0 14.5 2.22
717.0 21.8 3.18
718.0 27.6 4.29
719.0 30.0 5.40
719.4 161.2 5.80
719.9 442.9 6.38
ROUTE
0 0 0 8 1
711.0 0 0
712.0 7.3 0.54
713.0 18.9 1.35
714.0 43.6 2.23
716.0 85.7 4.23
717.5 106.0 5.94
718.0 261.0 6.51
```

```
718.5 551.8 7.08
NO PRINTOUT
TITLED CONFLUENCE
FOSTER BRANCH BELOW MOPAC POND AREA
AREA 8-FOSTER BR ABOVE SHOAL CR
0.13 0.62 0.43 53.8 81 66 41
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 8 WITH FOSTER BRANCH
* ROUTE THROUGH AREA 8 OF FOSTER BRANCH
TITLED ROUTE
FOSTER BRANCH ABOVE SHOAL CREEK
0 0 0 9 1
711 0 0
713 116 0.01
715 328 0.06
718 759 0.69
720 1106 2.50
722 1448 4.86
726 1664 11.70
730 2103 28.69
734 4534 69.70
PRINTOUT
TITLED CONFLUENCE
SHOAL CREEK BELOW FOSTER BRANCH
AREA 10-SHOAL CR ABOVE SHOAL CREEK BLVD.(ABOVE NW. PARK)
1.52 1.53 0.93 43.8 77 37 52
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 10 WITH SHOAL CREEK
PRINTOUT
OPTION 10 11
SKIPTO CALIB
ENDOPTION
OPTION 1
* ROUTE THROUGH AREA 10 OF SHOAL CREEK
TITLED ROUTE
SHOAL CREEK ABOVE INFLOW WEIR TO NW PARK POND
* HEC2 INDEX 3
0 0 0 10 1
668.000 0.000 0.000
669.300 200.000 5.700
670.500 500.000 10.600
671.900 1000.000 17.400
673.900 2000.000 28.700
677.500 5000.000 63.900
681.400 10000.000 136.300
684.300 15000.000 219.900
685.900 20000.000 325.600
688.100 30000.000 498.100
```

```
DISPLAY POINT
ENDOPTION
OPTION 2
TITLED ROUTE
SHOAL CREEK ABOVE INFLOW WEIR TO NW PARK POND
0 0 0 10 1
668.00 0.00 0.00
669.20 200.00 4.60
670.30 500.00 8.50
671.60 1000.00 14.00
673.50 2000.00 23.20
677.10 5000.00 45.30
680.90 10000.00 79.30
684.00 15000.00 136.60
685.70 20000.00 240.70
687.90 30000.00 402.40
DISPLAY POINT
ENDOPTION
OPTION 17
* HEC2 INDEX   3
TITLED ROUTE
SHOAL CREEK ABOVE INFLOW WEIR TO NW PARK POND
 0 0 0 10 1
    668.000        0.000        0.000
    669.200      200.000        4.900
    670.300      500.000        8.800
    671.600     1000.000       14.200
    673.500     2000.000       23.200
    677.100     5000.000       44.500
    680.900    10000.000       76.900
    684.000    15000.000      139.400
    685.700    20000.000      228.500
    687.900    30000.000      391.300
DISPLAY POINT
ENDOPTION
$LABEL$ CALIB
OPTION 10 11
* THIS IS THE ROUTE FROM MATT GOODWIN'S EXISTING RUN
TITLED ROUTE
SHOAL CREEK BELOW SHOAL CREEK BLVD.
0 0 0 11 1
662.70 0 0
663.65 100 4.99
663.98 200 8.19
664.59 500 16.36
665.37 1000 28.28
666.56 2000 51.05
671.43 5000 162.16
676.76 10000 350.16
678.78 15000 492.37
```

```
680.30 20000 639.04
683.14 30000 939.2
ENDOPTION
OPTION 7 29
DATA
ROUTE INITIALIZATION DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
ENDOPTION
OPTION 7
TITLED ROUTE
SHOAL CREEK BELOW DIVERSION INTO NW. PARK UPPER TUNNEL(DIAM. = 18.5')
0 0 0 3 1 3
0 0 0
1 0 9624
2 100000 9624
DISPLAY POINT
ENDOPTION
OPTION 29
TITLED ROUTE
SHOAL CREEK BELOW DIVERSION INTO NW. PARK UPPER TUNNEL(DIAM. = 14')
0 0 0 19 1 3
667.0 0 0
668.0 230 0
669.0 500 0
670.0 730 0
671.0 1000 0
672.0 1150 330
673.0 1300 1000
674.0 1430 1920
675.0 1600 3100
676.0 1800 4300
677.0 1950 4310
678.0 2400 4330
679.0 2900 4340
680.0 3900 4350
681.0 5800 4370
682.0 9000 4380
683.0 12000 4390
684.0 15000 4400
685.0 18300 4410
DISPLAY POINT
ENDOPTION
OPTION 3 5
DATA
```

```
ROUTE INITIALIZATION DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
PLOT FHG = ON
TITLED ROUTE
SHOAL CREEK BELOW DIVERSION INTO INFLOW WEIR
0 0 0 12 1 9
668 0 0
669.3 200 0
670.5 500 0
673.9 2000 0
676.1 3700 0
676.5 3959 41
677 4225 275
677.5 4357 643
678 4416 1134
679 4416 2478
680 4416 4312
681 4416 6654
ENDOPTION
OPTION 5
COPY_FHG
11
DISPLAY POINT
ENDOPTION
OPTION 10 11
SKIPTO CAL
ENDOPTION
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
OPTION 17
* HEC2 INDEX 4
TITLED ROUTE
SHOAL CREEK ABOVE OUTFLOW WEIR
0 0 0 10 1
659.400 0.000 0.000
660.800 200.000 2.700
661.800 500.000 5.000
663.100 1000.000 8.200
664.800 2000.000 13.100
668.400 5000.000 24.600
672.500 10000.000 42.900
```

```
674.400 15000.000 86.000
676.000 20000.000 147.200
678.000 30000.000 229.300
SKIPTO CAL
ENDOPTION
* HEC2 INDEX 10
TITLED ROUTE
SHOAL CREEK ABOVE OUTFLOW WEIR
0 0 0 10 1
659.400 0.000 0.000
661.600 200.000 3.000
663.400 500.000 5.600
665.400 1000.000 9.300
667.800 2000.000 14.900
673.200 5000.000 31.900
675.300 10000.000 49.100
676.400 15000.000 92.300
677.300 20000.000 151.700
678.800 30000.000 233.900
$LABEL$ CAL
OPTION 3 5
TITLED RESTORE
INFLOW TO NWP UPPER POND FROM SHOAL CREEK
9
DISPLAY POINT
ENDOPTION
AREA 10A - NORTHWEST PARK TRIB AT NORTHWEST PARK
0.26 0.88 0.45 75.8 74 66 42
OPTION 3 5
DATA
ROUTE INITIALIZATION DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
DISCHARGE
DIVERSION
TITLED ROUTE
NWP TRIBUTARY DIVERSION AROUND LOWER POND
0 0 0 3 1 10
0 0
0 290
100000 290
NO PRINTOUT
TITLED COMBINE
COMBINED INFLOW FHG INTO LOWER POND
ENDOPTION
OPTION 5
DATA
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
ROUTE INITIALIZATION DATA
DEFAULT
ALTERNATE RATING ENTRIES
RIVER RATING ENTRIES
RIVER FHG STORAGE
ROUTE SECOND DATA
RESET
PIPE INFLOW INVERT
ROUTE ALTERNATE TABLE
RESET
HEAD
DISCHARGE
ROUTE RIVER TABLE
RESET
ELEVATION
DISCHARGE
ROUTE DATA TABLE
DEFAULT
* ROUTE THROUGH NW PARK POND WITH FLOW DIVERTING OVER INLET WEIR
TITLED ROUTE
ROUTE THROUGH FACILITY W/BOTH PONDS OPERATING AS ONE
0 0 0 18 1 8 10 11
660 0 0
665 0 4.33
665.6 0 6.18
666 0 8.34
666.8 0 11.7
667.7 0 16.52
668.7 0 22.86
670.8 0 30.47
671.45 0 38.70
672.8 0 46.87
674.2 0 55.87
675 0 104
676.1 0 122
677 0 138
677.8 0 154
678 29.5 157
679 830 179
680 2270 195
* CREST ELEVATION OF INLET WEIR ###############
676.1
* ############### ############### ###############
* WEIR RATING CURVE
0 0
```

```
0.4 41
0.9 275
1.4 643
1.9 1134
2.9 2478
3.9 4312
4.9 6654
* ############### ############### ###############
* TAILWATER RATING CURVE
668 0
669.3 200
670.5 500
671.9 1000
673.9 2000
677.5 5000
681.4 10000
684.3 15000
685.9 20000
688.1 30000
DISPLAY POINT
ENDOPTION
OPTION 3
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
TITLED ROUTE
ROUTE THROUGH NW PARK POND WITH NO FLOW OVER INFLOW WEIR
0 0 0 18 1
660 0 0
665 0 4.33
665.6 0 6.18
666 0 8.34
666.8 0 11.7
667.7 0 16.52
668.7 0 22.86
670.8 0 30.47
671.45 0 38.70
672.8 0 46.87
674.2 0 55.87
675 0 104
676.1 0 122
677 0 138
677.8 0 154
678 21 157
679 792 179
680 2210 195
DISPLAY POINT
ENDOPTION
```

```
DATA
PLOT FREQ = OFF
NO PRINTOUT
OPTION 5
TITLED RESTORE
SHOAL CREEK BELOW INLET WEIR
11
* HEC2 INDEX 10
TITLED ROUTE
ROUTE SHOAL CREEK FROM INLET WEIR TO OUTFLOW WEIR
0 0 0 10 1
659.400 0.000 0.000
661.600 200.000 3.000
663.400 500.000 5.600
665.400 1000.000 9.300
667.800 2000.000 14.900
673.200 5000.000 31.900
675.300 10000.000 49.100
676.400 15000.000 92.300
677.300 20000.000 151.700
678.800 30000.000 233.900
DISPLAY POINT
DATA
DEBUG SLUICE = OFF
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
NO PRINTOUT
TITLED COMBINE
SHOAL CREEK ABOVE NWP TRIB #1 CONFLUENCE
ENDOPTION
OPTION 3 5
TITLED RESTORE
RESTORED FLOW FROM NWP TRIB. DIVERSION
10
PRINTOUT
TITLED COMBINE
NORTHWEST PARK TRIBUTARY ABOVE SHOAL CREEK
NO PRINTOUT
ENDOPTION
*USGS STREAM GAGING STATION AT NORTHWEST PARK
PRINTOUT
TITLED CONFLUENCE
SHOAL CREEK BELOW NORTHWEST PARK TRIB
NO PRINTOUT
OPTION 10 11
*SKIPTO END
```

```
ENDOPTION
DATA
ROUTE INITIALIZATION DATA
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
AREA 11-OAK HOLLOW POND TRIBUTARY HEADWATERS
0.13 0.66 0.27 165.7 57 66 54
TITLED ROUTE
OAK HOLLOW POND TRIB. BELOW OAK HOLLOW POND
0 0 0 9 1
722.8 0 0
726.0 18 0.30
728.0 29 0.68
732.0 40 2.17
736.0 50 4.72
740.0 59 8.33
744.0 68 13.08
751.7 92 26.40
753.0 246 29.20
AREA 12-OAK HOLLOW POND TRIB ABOVE SHOAL CR
0.19 0.33 0.27 52.5 57 56 54
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 12 WITH OAK HOLLOW POND TRIBUTARY
PRINTOUT
* ROUTE THROUGH AREA 12 OF OAK HOLLOW POND TRIBUTARY
TITLED ROUTE
ROUTING THROUGH AREA 12
0 0 0 10 1
691 0 0
695 90 0.82
696 123 2.23
698 155 6.00
700 230 10.20
702 265 14.83
702.5 275 16.10
703 396 17.40
703.5 573 18.70
704 895 19.90
TITLED ROUTE
OAK HOLLOW POND TRIB ABOVE SHOAL CREEK
```

```
0 0 0 9 1
684 0 0
688 120 0.92
690 180 2.95
692 220 4.33
694 260 7.06
694.5 270 7.80
695 368 8.60
695.5 515 9.40
696 789 10.16
PRINTOUT
TITLED CONFLUENCE
SHOAL CREEK BELOW OAK HOLLOW POND TRIB.
OPTION 2
DATA
INCLUDES-OPTIONS = 1
ENDOPTION
AREA 13-SHOAL CR ABOVE WHITE ROCK DR
0.27 0.55 0.32 26.7 78 43 41
NO PRINTOUT
TITLED COMBINE
COMBINING SHOAL CREEK ABOVE STREAM GAGE AT WHITE ROCK DRIVE
PRINTOUT
OPTION 1
TITLED ROUTE
SHOAL CREEK BELOW STREAM GAGE AT WHITE ROCK DRIVE
* HEC2 INDEX 4
0 0 0 10 1
646.400 0.000 0.000
648.200 200.000 4.900
649.100 500.000 9.100
650.300 1000.000 14.800
651.900 2000.000 25.100
654.800 5000.000 56.000
658.700 10000.000 106.200
661.100 15000.000 161.100
662.700 20000.000 211.200
665.300 30000.000 300.000
ENDOPTION
OPTION 17
* HEC2 INDEX 5
TITLED ROUTE
SHOAL CREEK BELOW STREAM GAGE AT WHITE ROCK DRIVE
0 0 0 10 1
645.180 0.000 0.000
646.350 200.000 4.330
647.180 500.000 7.720
648.180 1000.000 11.960
649.580 2000.000 19.010
652.400 5000.000 35.270
```

```
655.560 10000.000 65.590
657.300 15000.000 110.560
659.850 20000.000 166.480
662.370 30000.000 264.090
ENDOPTION
*USGS STREAM GAGING STATION AT WHITE ROCK DRIVE
DATA
PLOT FREQ = OFF
DISPLAY POINT
DATA
*FREQUENCY CURVE
*1M2PK*WITEPLOT
PLOT FREQ = OFF
AREA 14-SHOAL CR ABOVE HANCOCK CR
1.13 1.93 1.03 57.3 54 65 30
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 14 WITH SHOAL CREEK
OPTION 1
TITLED ROUTE
SHOAL CREEK ABOVE HANCOCK CREEK
* HEC2 INDEX 5
0 0 0 10 1
587.330 0.000 0.000
590.830 200.000 23.770
592.490 500.000 38.840
594.150 1000.000 57.800
596.030 2000.000 88.940
598.950 5000.000 169.250
601.490 10000.000 290.210
604.070 15000.000 396.370
609.210 20000.000 508.900
610.980 30000.000 743.700
ENDOPTION
OPTION 17
* HEC2 INDEX 6
TITLED ROUTE
SHOAL CREEK ABOVE HANCOCK CREEK
0 0 0 10 1
588.150 0.000 0.000
589.130 200.000 11.230
589.820 500.000 20.120
590.610 1000.000 31.760
591.810 2000.000 50.660
594.670 5000.000 96.570
598.340 10000.000 162.240
601.320 15000.000 228.760
603.910 20000.000 295.050
608.090 30000.000 433.510
ENDOPTION
```

```
DISPLAY POINT
AREA 15A - HANCOCK CREEK HEADWATERS ABOVE ARROYO SECA
0.13 0.51 0.20 68.0 90 66 47
DISPLAY POINT
AREA 15B - HANCOCK CREEK ABOVE PAYNE AVENUE
0.22 0.56 0.37 66.7 78 64 42
TITLED COMBINE
COMBINING AREA 15B WITH HANCOCK CREEK
TITLED ROUTE
HANCOCK CREEK BELOW PAYNE AVENUE
0 0 0 10 1
682.0 0 0
687.6 2071 25.2
687.9 3153 33.6
688.3 3893 38.6
688.5 4419 41.9
688.8 5166 46.7
689.0 5752 50.2
689.3 6350 53.8
689.8 8052 63.7
690.2 9478 71.8
DISPLAY POINT
AREA 15C - HANCOCK CREEK ABOVE TRIB H-1
0.33 0.97 0.52 27.5 90 50 49
TITLED COMBINE
COMBINING AREA 15C WITH HANCOCK CREEK
* ROUTE THROUGH AREA 15C OF HANCOCK CREEK
TITLED ROUTE
HANCOCK CREEK ABOVE TRIB. H-1
0 0 0 10 1
659.0 0 0
665.4 2071 21.4
666.0 3153 30.6
666.0 3893 35.1
666.1 4419 38.6
666.0 5166 43.4
666.1 5752 47.1
666.2 6350 50.7
666.4 8052 60.3
666.7 9478 67.9
DISPLAY POINT
AREA 15D - TRIB H-1 ABOVE HANCOCK CREEK
0.70 1.35 1.04 59.3 68 66 43
TITLED CONFLUENCE
HANCOCK CREEK BELOW TRIB H-1
DISPLAY POINT
AREA 15E - HANCOCK CREEK ABOVE BURNET ROAD
0.47 0.92 0.57 36.2 83 66 45
TITLED COMBINE
COMBINING AREA 15E WITH HANCOCK CREEK
```

```
* ROUTE THROUGH AREA 15E OF HANCOCK CREEK
OPTION -33
TITLED ROUTE
HANCOCK CREEK ABOVE BURNET ROAD
0 0 0 10 1
631.0 0 0
640.6 2071 46.7
644.5 3153 71.7
645.8 3893 89.6
646.4 4419 102.6
647.1 5166 120.4
647.6 5752 134.5
647.9 6350 147.4
648.8 8052 183.2
649.1 9478 209.5
DISPLAY POINT
ENDOPTION
OPTION 33
* ROUTE THRU AREA 15E
TITLED ROUTE
HANCOCK CREEK ABOVE BURNET ROAD
0 0 0 10 1
631.0 0 0
640.6 2071 38.1
644.5 3153 58.5
645.8 3893 73.1
646.4 4419 83.7
647.1 5166 98.2
647.6 5752 109.7
647.9 6350 120.2
648.8 8052 149.5
649.1 9478 170.9
DISPLAY POINT
ENDOPTION
OPTION 8
DATA
ROUTE INIT. DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
TITLED ROUTE
HANCOCK BELOW BURNET-BELOW FIRST INTAKE
0 0 0 3 1 1
0 0 0
1 0 5300
2 100000 5300
```

```
DISPLAY POINT
DATA
ROUTE INIT. DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
ENDOPTION
AREA 15F - HANCOCK CREEK ABOVE SHOAL CREEK
0.15 0.51 0.39 57.5 70 66 44
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 15F WITH HANCOCK CREEK
OPTION -33
* ROUTE THROUGH AREA 15F OF HANCOCK CREEK
TITLED ROUTE
HANCOCK CREEK ABOVE SHOAL CREEK
0 0 0 10 1
590.0 0 0
598.2 2071 20.4
605.1 3153 34.2
606.4 3893 44.8
607.4 4419 51.5
608.5 5166 61.4
609.3 5752 68.3
610.1 6350 74.5
612.2 8052 91.0
613.8 9478 99.8
DISPLAY POINT
ENDOPTION
OPTION 33
* ROUTE THRU AREA 15F
TITLED ROUTE
HANCOCK CREEK ABOVE SHOAL CREEK
0 0 0 10 1
590.0 0 0
598.2 2071 15.1
605.1 3153 25.2
606.4 3893 33.1
607.4 4419 38.1
608.5 5166 45.3
609.3 5752 50.4
610.1 6350 55.0
612.2 8052 67.2
613.8 9478 73.7
DISPLAY POINT
ENDOPTION
TITLED CONFLUENCE
SHOAL CREEK BELOW HANCOCK CREEK
DISPLAY POINT
OPTION 9
```

```
DATA
ROUTE INIT. DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
TITLED ROUTE
SHOAL CREEK BELOW 45TH ST. BELOW SECOND INTAKE
0 0 0 3 1 2
0 0 0
1 0 3900
2 100000 3900
DISPLAY POINT
DATA
ROUTE INIT. DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
ENDOPTION
AREA 16-SHOAL CR ABOVE W 34TH ST
0.95 1.35 0.84 24.7 68 61 40
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 16 WITH SHOAL CREEK
OPTION 1
TITLED ROUTE
SHOAL CREEK BELOW 34TH STREET
* HEC2 INDEX 6
0 0 0 10 1
547.000 0.000 0.000
550.200 200.000 10.930
551.400 500.000 20.360
552.700 1000.000 33.900
554.200 2000.000 57.860
557.900 5000.000 123.250
562.900 10000.000 223.090
565.300 15000.000 318.030
567.100 20000.000 433.400
569.900 30000.000 560.400
ENDOPTION
OPTION 17
* HEC2 INDEX 7
TITLED ROUTE
SHOAL CREEK BELOW 34TH STREET
0 0 0 10 1
546.780 0.000 0.000
547.940 200.000 12.270
```

```
548.690 500.000 21.370
549.610 1000.000 32.750
550.930 2000.000 50.940
553.580 5000.000 93.570
556.270 10000.000 152.790
558.180 15000.000 208.280
559.840 20000.000 259.550
562.500 30000.000 358.160
ENDOPTION
DISPLAY POINT
DATA
ROUTE INITIALIZATION DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
AREA 17-SHOAL CR ABOVE W 24TH ST
0.84 1.75 0.96 64.8 90 64 68
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 17 WITH SHOAL CREEK
PRINTOUT
OPTION 1
TITLED ROUTE
SHOAL CREEK BELOW 24TH STREET
* HEC2 INDEX 7
0 0 0 10 1
485.100 0.000 0.000
488.300 200.000 16.200
489.800 500.000 29.900
491.500 1000.000 49.000
493.500 2000.000 82.700
496.800 5000.000 161.300
500.300 10000.000 267.300
503.800 15000.000 369.900
505.900 20000.000 464.900
508.300 30000.000 633.200
ENDOPTION
OPTION 17
* HEC2 INDEX 8
TITLED ROUTE
SHOAL CREEK BELOW 24TH STREET
0 0 0 10 1
485.000 0.000 0.000
486.100 200.000 13.260
486.900 500.000 23.590
487.700 1000.000 36.430
488.900 2000.000 56.790
491.500 5000.000 105.300
494.400 10000.000 172.590
494.600 15000.000 232.990
```

```
496.400 20000.000 292.010
499.400 30000.000 417.140
ENDOPTION
DISPLAY POINT
*$$$$$$$$$$$$$$$$$$$$$$$$$
OPTION 19 25 28
DATA
ROUTE INIT. DATA
DEFAULT
DIVERSION STORAGE
ROUTE DATA TABLE
RESET
ELEVATION
DISCHARGE
DIVERSION
ENDOPTION
OPTION 19
TITLED ROUTE
SHOAL CREEK BELOW 19TH STREET TUNNEL INTAKE(18.5' DIAMETER)
0 0 0 3 1 4
0 0 0
1 0 6715
2 100000 6715
ENDOPTION
OPTION 25
TITLED ROUTE
SHOAL CREEK BELOW 19TH STREET TUNNEL INTAKE(16' DIAMETER)
0 0 0 3 1 4
0 0 0
1 0 4745
2 100000 4745
ENDOPTION
OPTION 28
TITLED ROUTE
SHOAL CREEK BELOW 19TH STREET TUNNEL INTAKE(14' DIAMETER)
0 0 0 12 1 4
478.0 0 0
482.0 50 0
488.0 100 3500
489.0 860 3540
490.0 2320 3580
491.0 4700 3600
492.0 7760 3640
493.0 11120 3680
494.0 14880 3720
495.0 19940 3760
496.0 23600 3800
497.0 28060 3840
ENDOPTION
OPTION 19 25 28
```

```
DISPLAY POINT
DATA
ROUTE INIT. DATA
DEFAULT
ROUTE DATA TABLE
DEFAULT
ENDOPTION
AREA 18-SHOAL CR ABOVE W 12TH ST
0.90 1.39 0.50 107.4 82 64 64
NO PRINTOUT
TITLED COMBINE
COMBINING AREA 18 WITH SHOAL CREEK
PRINTOUT
OPTION 1
TITLED ROUTE
SHOAL CREEK BELOW USGS GAGE AT 12TH STREET
* HEC2 INDEX 8
0 0 0 10 1
459.000 0.000 0.000
462.200 200.000 9.700
463.300 500.000 18.600
464.600 1000.000 30.500
467.000 2000.000 53.200
471.700 5000.000 113.300
477.000 10000.000 216.600
480.300 15000.000 325.000
482.200 20000.000 413.400
484.700 30000.000 559.700
ENDOPTION
OPTION 17
* HEC2 INDEX 9
TITLED ROUTE
SHOAL CREEK BELOW USGS GAGE AT 12TH STREET
0 0 0 10 1
458.340 0.000 0.000
459.290 200.000 7.600
459.940 500.000 13.280
460.780 1000.000 20.580
461.990 2000.000 32.550
464.820 5000.000 62.000
468.910 10000.000 108.010
473.130 15000.000 162.250
476.340 20000.000 238.810
479.050 30000.000 391.080
ENDOPTION
DATA
PLOT FREQ = OFF
DISPLAY POINT
DATA
PLOT FREQ = OFF
```

```
*FREQUENCY CURVE
*1M2PK*STREPLOT
*USGS STREAM GAGING STATION AT 12TH ST
OPTION 1
TITLED ROUTE
ROUTING THROUGH AREA 19 OF SHOAL CREEK
* HEC2 INDEX 9
0 0 0 10 1
426.000 0.000 0.000
427.000 200.000 12.100
427.500 500.000 21.700
428.200 1000.000 33.900
429.400 2000.000 53.500
432.100 5000.000 117.300
435.400 10000.000 293.800
438.000 15000.000 416.200
440.200 20000.000 529.000
444.000 30000.000 780.200
ENDOPTION
OPTION 17
* HEC2 INDEX 10
TITLED ROUTE
ROUTING THROUGH AREA 19 OF SHOAL CREEK
0 0 0 10 1
426.000 0.000 0.000
427.200 200.000 7.200
428.100 500.000 13.020
429.200 1000.000 20.520
430.800 2000.000 32.650
434.200 5000.000 61.900
438.200 10000.000 105.090
441.400 15000.000 150.250
444.200 20000.000 227.890
448.800 30000.000 435.720
ENDOPTION
AREA 19-SHOAL CR ABOVE COLORADO RIVER
0.40 0.97 0.62 41.2 88 68 70
TITLED COMBINE
SHOAL CREEK ABOVE TOWN LAKE
OPTION -7 -14 -20
SKIPTO END
ENDOPTION
$LABEL$ OPT20
*
* LAKE AUSTIN ROUTING DATA
*
OPTION 7 14 20
DATA
ROUTE PRINTOUT
3 3 3 3 3 3 3 3 3
```

```
COMBINE PRINTOUT
3 3 3 3 3 3 3 3 3
LOCAL PRINTOUT
3 3 3 3 3 3 3 3 3
UHG DATA
RESET
LENGTH
LCA
UHG TP
UHG CP 640
AREA 25 - COLORADO RIVER FROM LAKE TRAVIS TO LAKE AUSTIN
59.61 23.6 9.3 3.02 500
DISPLAY POINT
AREA 26 - BULL CREEK ABOVE COLORADO RIVER
31.63 12.4 6.1 2.38 500
PRINTOUT
TITLED CONFLUENCE
LAKE AUSTIN INFLOW WITHOUT SHOAL CREEK DIVERSION TUNNELS
NO PRINTOUT
ENDOPTION
OPTION 7 14
TITLED RESTORE
DIVERTED FLOW FROM UPPER TUNNEL ON SHOAL CREEK AT NW PARK
3
DISPLAY POINT
ENDOPTION
OPTION 14
TITLED COMBINE
TOTAL INFLOW INTO LAKE AUSTIN INCLUDING ONLY SHOAL CREEK AT NW PARK TUNNEL
DISPLAY POINT
ENDOPTION
TITLED ROUTE
LAKE AUSTIN OUTFLOWS
0 0 19700 17 1
480 0 4500
482 0 6500
484 0 8500
486 0 10700
488 0 13500
490 0 16400
492 0 19700
494 59300 23400
496 147400 26600
498 182100 30000
500 219700 33500
502 260200 37000
504 306900 40500
506 354300 44000
508 405100 47500
510 459200 51000
```

```
512 516000 54500
DISPLAY POINT
ENDOPTION
$LABEL$ END
```

TABLE C-12

EXECUTED ON 23 SEP 89 AT 13:17:07

SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
EXPECTED PROBABILITY DISCHARGE OPTION 15

INDEX	LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
NEW TRIB----------											
20	N.BALCONES TRIB BELOW MOPAC RR	0.43	194.	292.	809.	1019.	1103.	1171.	1256.	1473.	1505.
NEW TRIB----------											
26	S. BALCONES TRIB BELOW MOPAC RR	0.33	361.	539.	916.	1131.	1326.	1473.	1621.	1967.	2211.
NEW TRIB----------											
46	FOSTER BRANCH ABOVE SHOAL CREEK	1.48	783.	1077.	1752.	2091.	2750.	3438.	4154.	5873.	6556.
NEW TRIB----------											
66	OAK HOLLOW POND TRIB ABOVE SHOAL CREEK	0.32	125.	152.	224.	265.	540.	664.	1097.	1452.	1641.
NEW TRIB----------											
81	AREA 15D - TRIB H-1 ABOVE HANCOCK CREEK	0.70	343.	533.	1174.	1587.	1905.	2147.	2440.	3085.	3278.
NEW TRIB----------											
74	AREA 15A - HANCOCK CREEK HEADWATERS ABOVE ARROYO SECA	0.13	116.	172.	380.	465.	542.	603.	682.	900.	900.

TABLE C-12 (CONT'D)

EXECUTED ON 23 SEP 89 AT 13:17:08

SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
EXPECTED PROBABILITY DISCHARGE OPTION 15

INDEX	LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
77	HANCOCK CREEK BELOW PAYNE AVENUE	0.35	192.	316.	706.	871.	1047.	1184.	1345.	1665.	1818.
80	HANCOCK CREEK ABOVE TRIB. H-1	0.68	370.	660.	1284.	1617.	1925.	2176.	2490.	3122.	3399.
82	HANCOCK CREEK BELOW TRIB H-1	1.38	707.	1182.	2436.	3177.	3798.	4286.	4888.	6156.	6661.
85	HANCOCK CREEK ABOVE BURNET ROAD	1.85	729.	1177.	2417.	3212.	3898.	4417.	5060.	6357.	7152.
88	HANCOCK CREEK ABOVE SHOAL CREEK	2.00	764.	1213.	2422.	3297.	4017.	4577.	5250.	6695.	7557.
MAIN STEM----------											
4	SHOAL CREEK BELOW RR CULVERT AT A-1 DIVERSION	0.85	119.	168.	264.	330.	402.	459.	523.	618.	669.
11	COMBINED INFLOW INTO THE HIGHWAY 183 CULVERTS	1.59	1422.	2152.	3211.	3779.	4401.	4900.	5522.	7098.	7260.
12	SHOAL CREEK BELOW HWY 183 CULVERTS	1.59	889.	1026.	1176.	1235.	1283.	1315.	1351.	1386.	1415.
16	SHOAL CREEK BELOW CONFLUENCE OF RR UNDERPASS DIVERSION	1.59	991.	1184.	1439.	1617.	1814.	1987.	2239.	3201.	3910.
18	SHOAL CREEK ABOVE N. BALCONES TRIBUTARY	2.13	1414.	2026.	2720.	3083.	3526.	3865.	4313.	5597.	5823.
21	SHOAL CREEK BELOW CONFLUENCE WITH AREA 4A-N BALCONES TRIB	2.56	1597.	2299.	3496.	4072.	4595.	4998.	5525.	7013.	7310.
22	SHOAL CREEK ABOVE S. BALCONES TRIB. (AT STECK AVENUE)	2.56	1362.	1927.	2622.	3062.	3497.	3837.	4257.	5274.	6047.
27	SHOAL CR. BELOW S. BALCONES TRIBUTARY	2.89	1544.	2236.	3132.	3742.	4458.	4989.	5654.	7227.	7972.
29	SHOAL CREEK BELOW CONFLUENCE OF DIVERSION FROM S. BALCONES TRIB.	2.89	1544.	2236.	3132.	3742.	4458.	4989.	5654.	7227.	7972.

TABLE C-12 (CONT'D)

EXECUTED ON 23 SEP 89 AT 13:17:09

SHOAL CREEK
INTERIM REPORT
WITHOUT PROJECT

SHOAL CREEK * INTERIM REPORT * WITHOUT PROJECT
EXPECTED PROBABILITY DISCHARGE OPTION 15

INDEX	LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
32	SHOAL CREEK ABOVE FOSTER BRANCH (BELOW ANDERSON LANE)	3.13	1688.	2409.	3446.	4110.	4820.	5336.	5969.	7398.	8230.
47	SHOAL CREEK BELOW FOSTER BRANCH	4.61	2297.	3419.	5129.	6113.	7410.	8603.	9922.	12992.	14527.
50	SHOAL CREEK ABOVE INFLOW WEIR TO EH&A POND	6.13	2951.	4759.	6988.	8309.	9861.	11074.	12626.	16142.	18301.
60	SHOAL CREEK BELOW NORTHWEST PARK TRIB	6.39	2901.	4322.	4889.	6881.	9316.	11162.	12900.	16618.	18357.
67	SHOAL CREEK BELOW OAK HOLLOW POND TRIB.	6.71	3017.	4451.	5061.	7113.	9796.	11640.	13380.	17315.	19304.
70	SHOAL CREEK BELOW STREAM GAGE AT WHITE ROCK DRIVE	6.98	3037.	4527.	5310.	6516.	9492.	11037.	13754.	17617.	19670.
73	SHOAL CREEK ABOVE HANCOCK CREEK	8.11	2924.	4273.	5860.	7111.	9637.	11481.	15294.	19678.	22161.
89	SHOAL CREEK BELOW HANCOCK CREEK	10.11	3514.	5191.	7973.	9925.	12756.	15174.	19834.	25248.	28540.
92	SHOAL CREEK BELOW 34TH STREET	11.06	3492.	5043.	8378.	10637.	13287.	15496.	20537.	27571.	31091.
95	SHOAL CREEK BELOW 24TH STREET	11.90	3395.	4782.	8117.	10489.	13265.	15497.	20347.	27279.	30916.
98	SHOAL CREEK BELOW USGS GAGE AT 12TH STREET	12.80	3359.	4662.	7867.	10269.	13043.	15292.	20057.	27608.	31172.
101	SHOAL CREEK ABOVE TOWN LAKE	13.20	3275.	4516.	7258.	9606.	12584.	14797.	19347.	26346.	29768.

TABLE C-13

EXECUTED ON 28 SEP 89 AT 10:51:21

SHOAL CREEK
INTERIM REPORT
WITH PROJECT

SHOAL CREEK * INTERIM REPORT * RECOMMENDED PLAN
EXPECTED PROBABILITY DISCHARGE OPTION 12

INDEX LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
NEW TRIB----------										
20 N.BALCONES TRIB BELOW MOPAC RR	0.43	194.	292.	809.	1019.	1103.	1171.	1256.	1473.	1505.
NEW TRIB----------										
26 S. BALCONES TRIB BELOW MOPAC RR	0.33	361.	539.	916.	1131.	1326.	1473.	1621.	1967.	2211.
NEW TRIB----------										
46 FOSTER BRANCH ABOVE SHOAL CREEK	1.48	783.	1077.	1752.	2091.	2750.	3438.	4154.	5873.	6556.
NEW TRIB----------										
67 OAK HOLLOW POND TRIB ABOVE SHOAL CREEK	0.32	125.	152.	224.	265.	540.	664.	1097.	1452.	1641.
NEW TRIB----------										
75 AREA 15A - HANCOCK CREEK HEADWATERS ABOVE ARROYO SECA	0.13	116.	172.	380.	465.	542.	603.	682.	900.	900.
78 HANCOCK CREEK BELOW PAYNE AVENUE	0.35	192.	316.	706.	871.	1047.	1184.	1345.	1665.	1818.
81 HANCOCK CREEK ABOVE TRIB. H-1	0.68	370.	660.	1284.	1617.	1925.	2176.	2490.	3122.	3399.

TABLE C-13 (CONT'D)

EXECUTED ON 28 SEP 89 AT 10:51:22

SHOAL CREEK
INTERIM REPORT
WITH PROJECT

SHOAL CREEK * INTERIM REPORT * RECOMMENDED PLAN
EXPECTED PROBABILITY DISCHARGE OPTION 12

INDEX LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
83 HANCOCK CREEK BELOW TRIB H-1	1.38	707.	1182.	2436.	3177.	3798.	4286.	4888.	6156.	6661.
86 HANCOCK CREEK ABOVE BURNET ROAD	1.85	767.	1208.	2495.	3375.	4119.	4660.	5344.	6714.	7452.
89 HANCOCK CREEK ABOVE SHOAL CREEK	2.00	790.	1276.	2586.	3480.	4247.	4812.	5522.	6947.	7820.
MAIN STEM----------										
4 SHOAL CREEK BELOW RR CULVERT AT A-1 DIVERSION	0.85	119.	168.	264.	330.	402.	459.	523.	618.	669.
11 COMBINED INFLOW INTO THE HIGHWAY 183 CULVERTS	1.59	1422.	2152.	3211.	3779.	4401.	4900.	5522.	7098.	7260.
12 SHOAL CREEK BELOW HWY 183 CULVERTS	1.59	1196.	1754.	2093.	2460.	2861.	3107.	3384.	3977.	4274.
16 SHOAL CREEK BELOW CONFLUENCE OF RR UNDERPASS DIVERSION	1.59	1298.	1922.	2373.	2814.	3298.	3628.	4015.	4870.	5265.
18 SHOAL CREEK ABOVE N. BALCONES TRIBUTARY	2.13	1720.	2708.	3567.	4002.	4591.	5120.	5772.	7269.	7642.
21 SHOAL CREEK BELOW CONFLUENCE WITH AREA 4A-N BALCONES TRIB	2.56	1899.	2976.	4342.	4989.	5658.	6249.	6981.	8684.	9129.
22 SHOAL CREEK ABOVE S. BALCONES TRIB. (AT STECK AVENUE)	2.56	1743.	2780.	3984.	4639.	5264.	5667.	6230.	7382.	7994.
27 SHOAL CR. BELOW S. BALCONES TRIBUTARY	2.89	1921.	3085.	4488.	5312.	6222.	6815.	7623.	9329.	10180.
29 SHOAL CREEK BELOW CONFLUENCE OF DIVERSION FROM S. BALCONES TRIB.	2.89	1921.	3085.	4488.	5312.	6222.	6815.	7623.	9329.	10180.
32 SHOAL CREEK ABOVE FOSTER BRANCH (BELOW ANDERSON LANE)	3.13	2113.	3454.	5032.	5888.	6888.	7565.	8349.	10009.	10605.

TABLE C-13 (CONT'D)

EXECUTED ON 28 SEP 89 AT 10:51:23

SHOAL CREEK
INTERIM REPORT
WITH PROJECT

SHOAL CREEK * INTERIM REPORT * RECOMMENDED PLAN
EXPECTED PROBABILITY DISCHARGE OPTION 12

INDEX	LOCATION	DA-SQ.MI	PERCENT CHANCE EXCEEDENCE 99.99	50	20	10	4	2	1	0.2	SPF
47	SHOAL CREEK BELOW FOSTER BRANCH	4.61	2700.	4440.	6685.	7855.	9449.	10801.	12265.	15564.	17050.
50	SHOAL CREEK ABOVE INFLOW WEIR TO NW PARK POND	6.13	3444.	5958.	9027.	10517.	12157.	13677.	15389.	18057.	20766.
51	SHOAL CREEK BELOW DIVERSION INTO NW. PARK UPPER TUNNEL(DIAM. = 14')	6.13	1442.	1780.	4668.	6146.	7781.	9295.	11004.	13666.	16361.
61	SHOAL CREEK BELOW NORTHWEST PARK TRIB	6.39	1505.	1876.	4205.	4921.	5046.	7110.	10695.	14028.	16683.
68	SHOAL CREEK BELOW OAK HOLLOW POND TRIB.	6.71	1626.	2007.	4374.	5144.	5332.	7580.	11116.	14726.	17626.
71	SHOAL CREEK BELOW STREAM GAGE AT WHITE ROCK DRIVE	6.98	1719.	2234.	4295.	5158.	5600.	7300.	10295.	14386.	17677.
74	SHOAL CREEK ABOVE HANCOCK CREEK	8.11	1814.	2294.	4640.	6144.	7075.	8493.	11034.	16324.	19373.
90	SHOAL CREEK BELOW HANCOCK CREEK	10.11	2545.	3445.	6991.	9380.	10983.	12455.	14925.	21683.	25425.
93	SHOAL CREEK BELOW 34TH STREET	11.06	2654.	3555.	7300.	9810.	11715.	13466.	16155.	22208.	27344.
96	SHOAL CREEK BELOW 24TH STREET	11.90	2667.	3461.	6971.	9454.	11534.	13283.	16073.	22470.	27160.
97	SHOAL CREEK BELOW 19TH STREET TUNNEL INTAKE(14' DIAMETER)	11.90	87.	98.	3385.	5840.	7895.	9615.	12382.	18751.	23363.
100	SHOAL CREEK BELOW USGS GAGE AT 12TH STREET	12.80	569.	848.	3091.	5681.	7808.	9546.	12058.	18755.	22937.
103	SHOAL CREEK ABOVE TOWN LAKE	13.20	627.	884.	2914.	5321.	7072.	8705.	11291.	18142.	21781.

TABLE C-14

Shoal Creek
Interim Report

Comparison Summary for With and Without Conditions

LOCATION		Expected Probability Discharges	
		1% CHANCE EXCEEDENCE	SPF
Shoal Creek Above diversion into Northwest Park upper tunnel	Existing	12626.	18301.
	Improved	15389.	20766.
Shoal Creek Below diversion into Northwest Park upper tunnel	Existing	12626.	18301.
	Improved	11004.	16361.
Diverted flow through Northwest Park upper tunnel	Existing	++++	++++
	Improved	4384.*	4404.*
Hancock Creek Above confluence with Shoal Creek	Existing	5250.	7557.
	Improved	5522.	7820.
Shoal Creek Above diversion into lower tunnel at 19th Street	Existing	20347.	30916.
	Improved	16073.	27160.
Shoal Creek Below diversion into lower tunnel at 19th Street	Existing	20347.	30916.
	Improved	12382.	23363.
Diverted flow from Shoal Creek into Lower tunnel intake at 19th Street	Existing	++++	++++
	Improved	3681.*	3797.*

* Computed probability discharges

TABLE C-15

Shoal Creek
Interim Report

Pertinent Data on Northwest Park Detention Facility

Invert Elevation of:	
Inflow weir	676.10 NGVD
Outflow weir	677.80 NGVD
Outflow pipe	661.00 NGVD
City of Austin Pond Elevation for Design Flood	682.00 NGVD
Approximate length of inflow weir	340 Feet
Approximate length of outflow weir	250 Feet
Approximate storage at top of levee	195 ac-ft
Maximum Inflow Discharge	6650 cfs
Maximum Outflow Discharge	3500 cfs

Table C-16

Shoal Creek
Interim Report
Austin, Texas

Lake Austin Peak Inflow / Maximum Pool Elevations
Without and With Shoal Creek Tunnel Diversion at
Northwest Park

%-Chance Exceedence	Without Diversion		With Diversion		Net Increase in Pool Elevation (feet)
	Peak Inflow(cfs)	Maximum Pool Elevation (NGVD)	Peak Inflow(cfs)	Maximum Pool Elevation (NGVD)	
99.99	11673	492.34	11673	492.34	<0.01
50	20724	492.61	20724	492.61	<0.01
20	34109	493.02	34109	493.02	<0.01
10	45082	493.36	45082	493.37	0.01
4	57392	493.75	57392	493.76	0.01
2	67926	494.07	67981	494.09	0.02
1	79301	494.36	79558	494.38	0.02
0.2	113384	495.14	114703	495.18	0.04
SPF	138423	495.68	140342	495.72	0.04

Notes:

(1) Storm is critically centered on Shoal Creek and the Colorado River below Lake Travis

(2) No releases from Lake Travis are assumed.

(3) All peak inflows represent computed, not expected, probability conditions.

(4) Lake Austin initial pool elevation assumed at 492 NGVD.

(5) Lake Austin elevation - storage - outflow relationship adopted from Travis County FIS, dated 1979. See Table C-17.

TABLE C-17

Shoal Creek
Interim Report
Austin, Texas

Lake Austin Pool Elevation - Storage - Outflow Relationship

Pool Elevation (NGVD)	Storage (AC-FT)	Outflow (CFS)
492	19700	0
494	23400	59300
496	26600	147400
498	30000	182100
500	33500	219700
502	37000	260200
504	40500	306900
506	44000	354300
508	47500	405100
510	51000	459200

Table C-18

Shoal Creek
Interim Report
Austin, Texas

Summary of Tunnel Outflows/Volumes

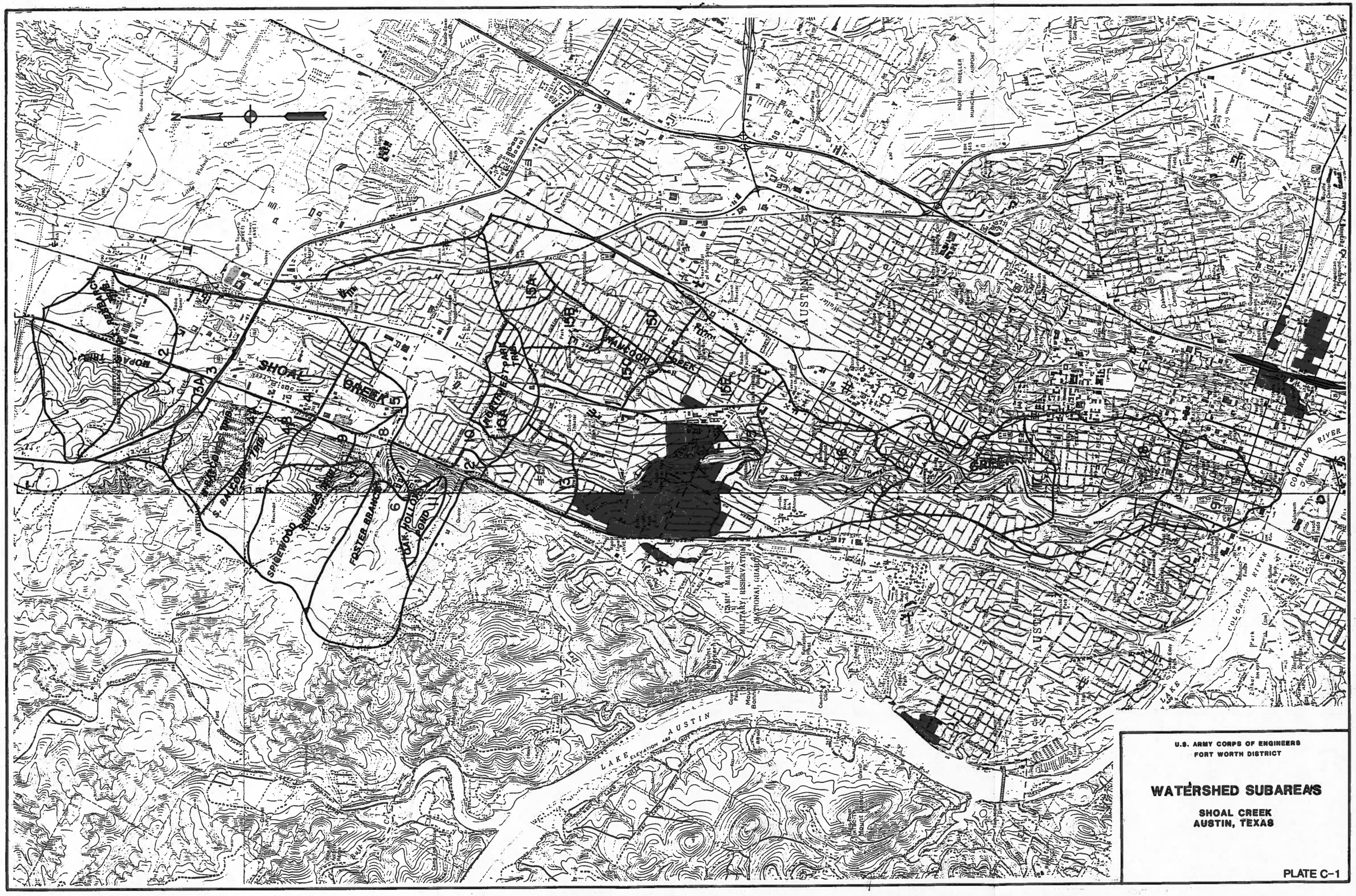
%-Chance Exceedence	Northwest Park Upper Tunnel		19th Street Lower Tunnel	
	Peak Discharge (CFS)	Diverted Volume (AC-FT)	Peak Discharge (CFS)	Diverted Volume (AC-FT)
99.99	2002	125	2580	777
50	4178	247	3363	998
20	4357	416	3587	1418
10	4371	553	3613	1683
4	4375	679	3638	1951
2	4380	800	3656	2256
1	4384	944	3681	2689
0.2	4394	1730	3738	4427
SPF	4404	2204	3797	6571

Notes:

(a) Northwest Park tunnel discharges into Lake Austin.

(b) 19th Street tunnel discharges into Town Lake.

(c) All peak discharges represent computed, not expected, probability conditions.

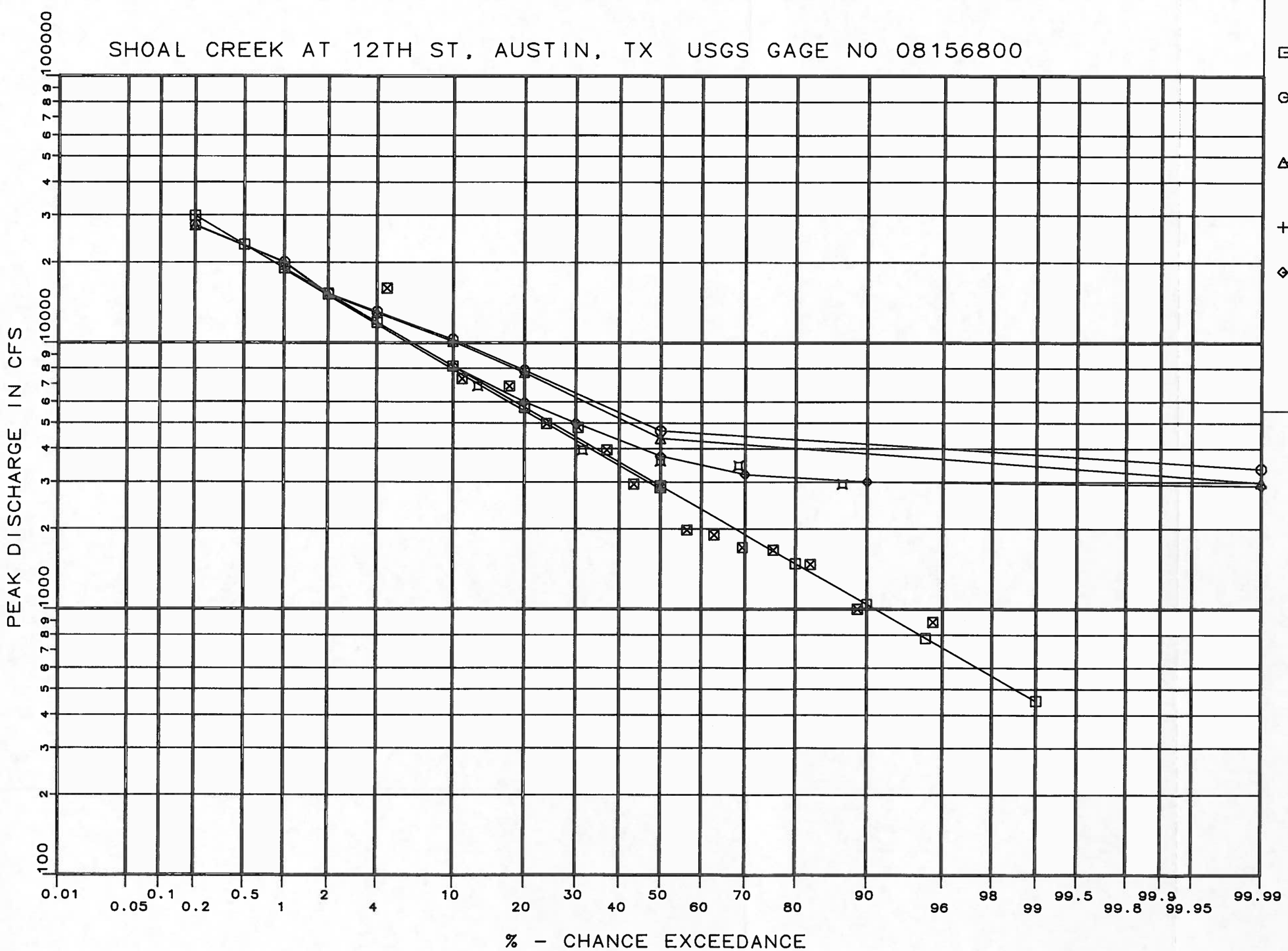


U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT

WATERSHED SUBAREAS

SHOAL CREEK
AUSTIN, TEXAS

PLATE C-1



LEGEND

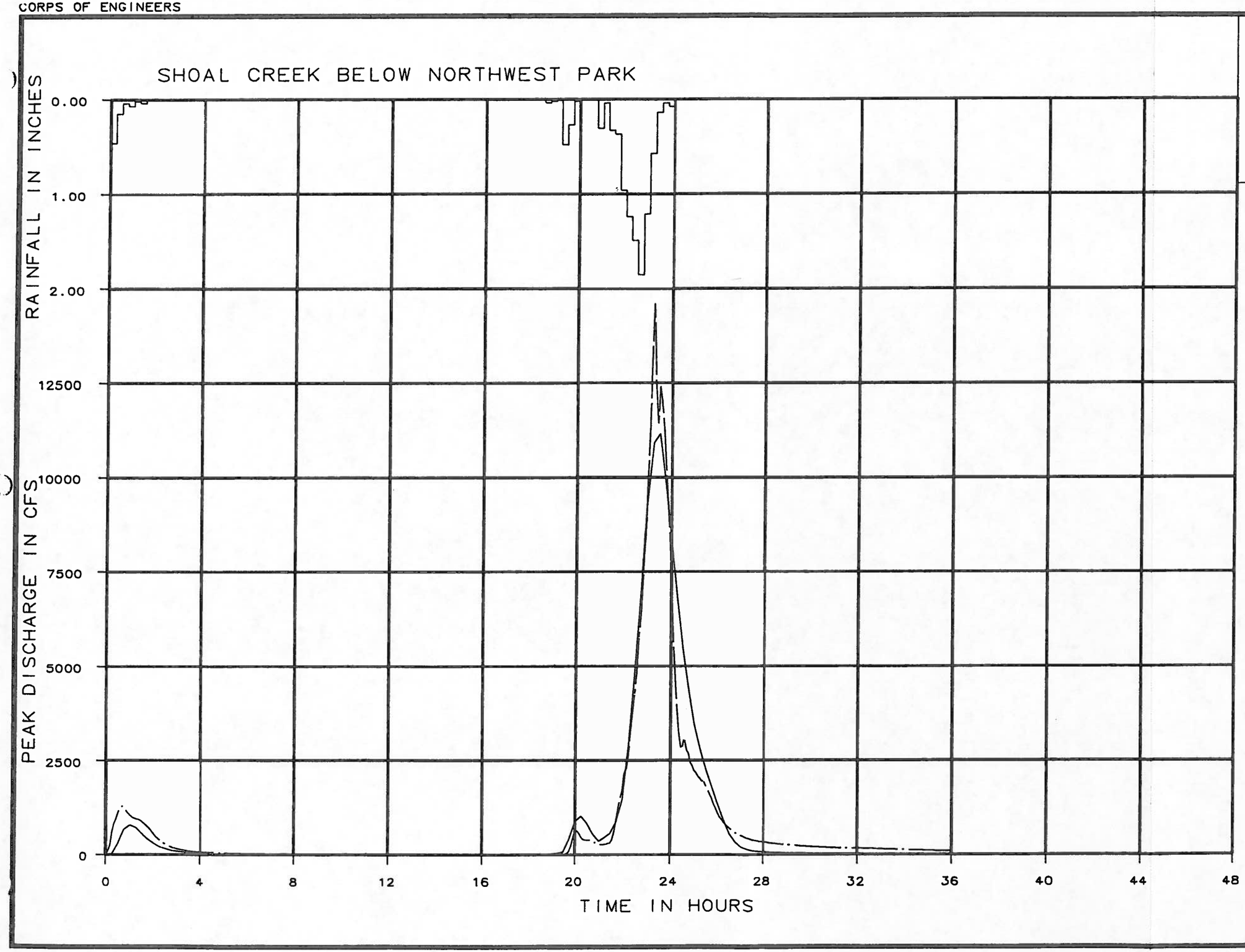
- ANNUAL SERIES 1975-1989
- SYNTHETIC MODEL CURVE - BASE YEAR 1999 CONDITIONS
- SYNTHETIC MODEL CURVE - 1986 CONDITIONS
- USGS AUSTIN URBAN STUDY
- PARTIAL DURATION CURVE
- OBSERVED ANNUAL DATA
- PARTIAL DURATION DATA 1985-1989

21 MAY 90

COLORADO RIVER BASIN
FLOOD FLOW FREQUENCY ANALYSIS
SHOAL CREEK INTERIM REPORT
AUSTIN, TEXAS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH
DA = 12.3 SQ MI

PLATE C-2

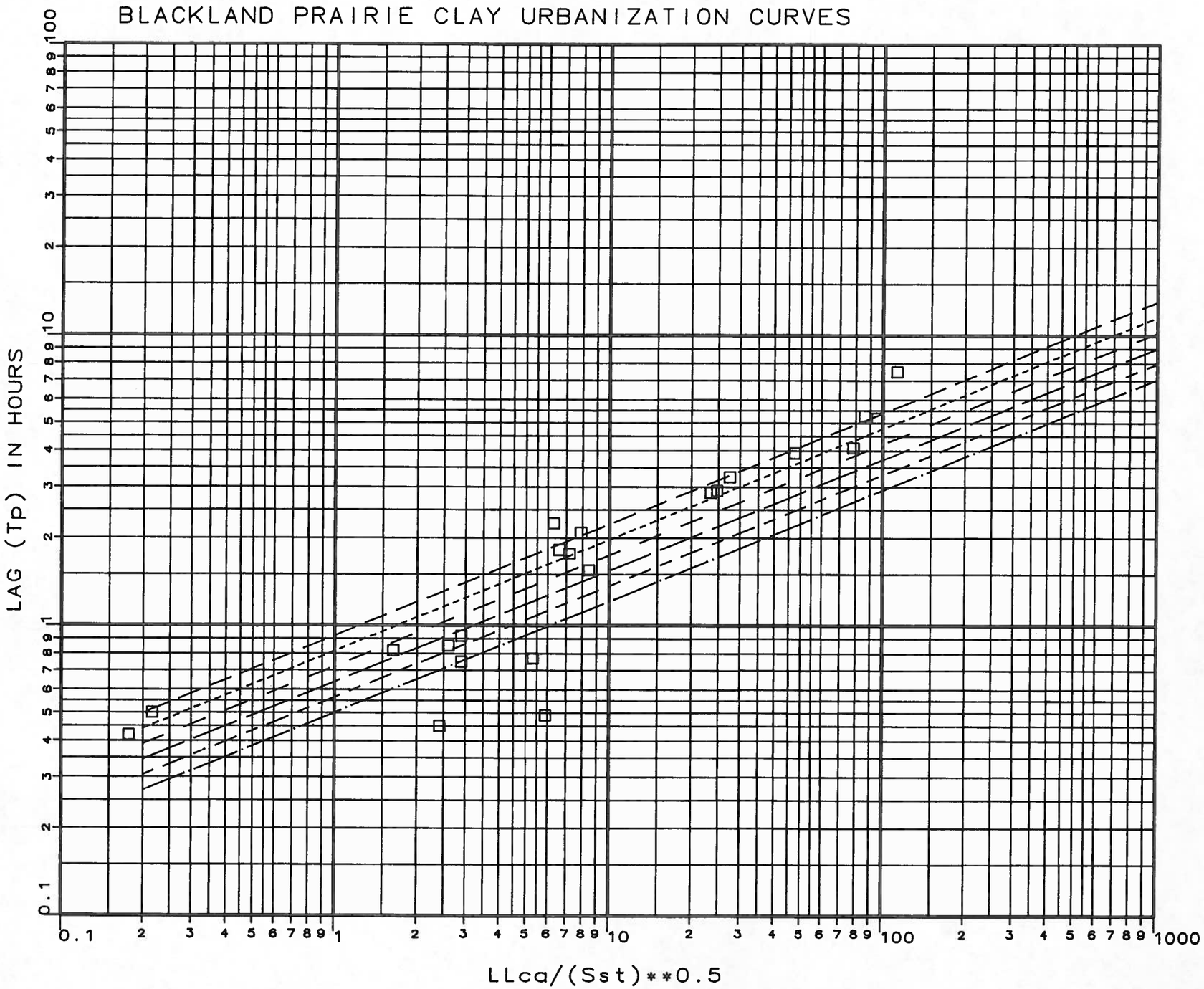


14 OCT 86

COLORADO RIVER BASIN
MAY 24, 1981 STORM REPRODUCTION
SHOAL CREEK
AUSTIN, TEXAS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-3



LEGEND

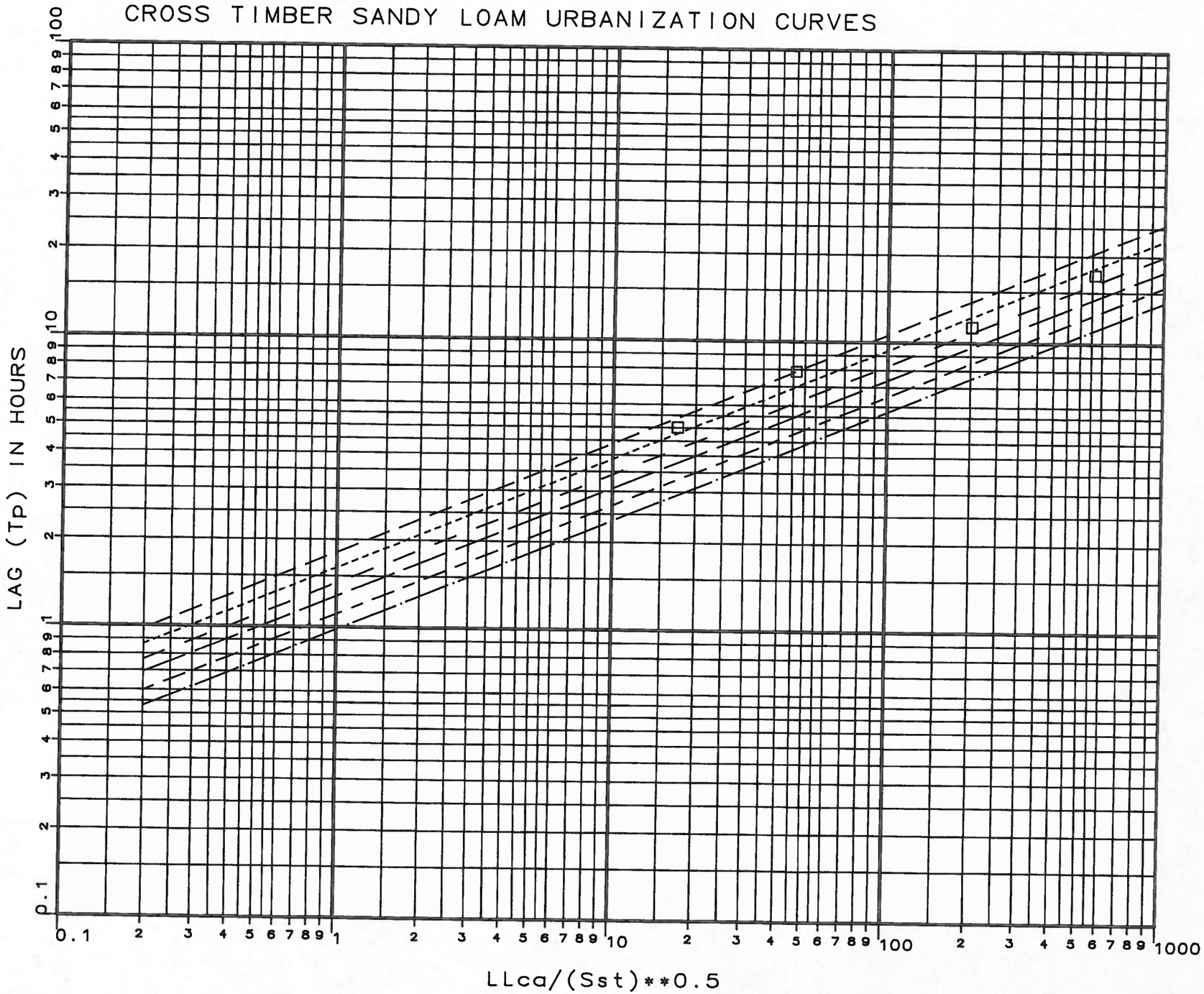
- □ DATA POINTS FROM TABLE C-8
- 100% URBANIZATION
- 80% URBANIZATION
- 60% URBANIZATION
- 40% URBANIZATION
- 20% URBANIZATION
- 0% URBANIZATION

21 MAY 90

WATERSHED LAG (Tp) VS. WATERSHED CHARACTERISTICS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-4



LEGEND

- □ DATA POINTS FROM TABLE C-9
- 100% URBANIZATION
- 80% URBANIZATION
- 60% URBANIZATION
- 40% URBANIZATION
- 20% URBANIZATION
- 0% URBANIZATION

21 MAY 90

WATERSHED LAG (Tp) VS. WATERSHED CHARACTERISTICS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-5

APPENDIX D

HYDRAULIC ANALYSIS

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APPENDIX D

HYDRAULIC ANALYSIS
SHOAL CREEK
AUSTIN, TEXAS

GENERAL

A study was performed on Shoal Creek and the major tributary, Hancock Creek, in Austin, Texas, to determine the hydraulic characteristics of the existing conditions and various combinations of improvements to alleviate flooding along the creeks. Water surface profiles were determined for the 1, 2, 5, 10, 25, 50, 100, and 500-year flood events and the standard project flood and used as a basis for determining the most feasible and economical protection.

The computations for determining the water surface profiles were made using the September 1982 version of the HEC-2, Water Surface Profiles computer program. The cross section information used in the HEC-2 hydraulic models was obtained from field surveys and City of Austin 2-foot contour interval topographic maps. Bridge data was obtained from the Texas Department of Highways and Public Transportation, the City of Austin Department of Public Works, and the Missouri-Pacific Railroad Company. The cross section data in the HEC-2 model was input looking upstream, left to right.

EXISTING CONDITIONS

SHOAL CREEK

The Shoal Creek drainage area is 13.2 square miles and is highly developed commercially and residentially. A large percentage of storm flows enter Shoal Creek from the developed areas designed to discharge storm flows rapidly. Flow in Shoal Creek is impeded by gravel shoals, bends, vegetation, small bridges, and developments which have encroached upon the water course. Portions of Shoal Creek consist of limestone streambeds which allow high flow velocities. Field observations after the Memorial Day flood of 1981 indicated little effects of scour on the streambanks. Existing condition water surface profiles for Shoal Creek were computed with limits extending from the confluence of Shoal Creek and the Colorado River to upstream of the Missouri-Pacific Railroad bridge, approximately 10 miles in length. Starting water surface elevations were determined from a rating curve of coincident flows at the confluence of Shoal Creek and the Colorado River. The hydraulic models incorporated Manning's roughness coefficients determined from field observation and aerial photographs. Values for the existing channel ranged from 0.040 to 0.060. The overbank roughness coefficient values ranged from 0.020 to 0.120. Contraction and expansion coefficients at most cross sections were 0.10 and 0.30 and increased at bridges to 0.30 and 0.50.

The existing conditions hydraulic model for Shoal Creek was calibrated as closely as possible to high water marks established after the Memorial Day flood of 1981 and USGS stream gage data. The stream gages are located at Steck Avenue, White Rock Drive, 12th Street, and Northwest Park (upstream of Shoal Creek Boulevard) and are flood-hydrograph, partial-record stations. The period of record of the gages is less than twelve years.

The hydraulic model of the 1981 flood was the basis for establishing the existing conditions hydraulic model. The 1981 flood water surface profiles, with observed high water marks, are shown on plates D-1 through D-7.

To adequately model the existing conditions, it was necessary to assume some blockage of existing bridges by debris accumulation. It was also assumed flood event flows which were contained in the channel would not produce large debris transport, and flood events which had significant overbank flow would produce sufficient debris transport to cause blockage at bridges. The water surface profiles for the 1, 2, 5, and 10-year flood events were computed using unrestricted bridge openings. Profiles for the 25, 50, 100, 500-year, and the standard project flood were computed with a percentage of each bridge opening restricted. The values for the percentage of bridge area reduction used in the model were coordinated with the city of Austin Engineering Department and are consistent with field observations of the Memorial Day flood of 1981 as many of the bridges were blocked by debris, fallen trees, and automobiles carried downstream by the flood flows. The debris accumulation which occurred in the Memorial Day flood is considered to be typical when flows of that magnitude occur. The 1981 flood profile is on average approximately 1.0 foot higher than the high water marks as indicated. An investigation of the validity of some high water marks and the accuracy of their horizontal location as well as estimate of the percentage of bridge blockage provided by the City of Austin will be completed and the results provided in the subsequent Design Memorandum.

The Shoal Creek existing conditions hydraulic model incorporated the following improvements of Shoal Creek by the city of Austin:

a. Removal of bridge at Silverway Drive.
b. New bridge at White Rock Drive and related channel improvement.
c. New bridge at Greenlawn Parkway and related channel improvement.
d. Northwest Park Detention facility and channel improvement from Shoal Creek Boulevard to Greenlawn Parkway.
e. Channel improvement (about 3,200 feet) upstream of West 34th Street.

The Shoal Creek existing conditions water surface profiles are shown on plates D-8 through D-14.

HANCOCK CREEK

The Hancock Creek drainage area is 2 square miles and is highly developed commercially and residentially. Hancock Creek contributes

substantial flows into Shoal Creek. Existing condition water surface profiles for Hancock Creek were computed with limits from the confluence of Hancock Creek and Shoal Creek to about two miles upstream. The starting water surface elevations were determined from a rating curve of coincident flows at the confluence of Shoal Creek and Hancock Creek. The cross section information used in the existing conditions model was obtained from city of Austin 2-foot contour interval topographic maps. Manning's roughness coefficients were determined from field observations and aerial photographs. The roughness coefficients used for the existing channel ranged from 0.030 to 0.090. The overbank values ranged from 0.035 to 0.150. Hancock Creek existing conditions water surface profiles are shown on plates D-15 and D-16.

SELECTED PLAN

GENERAL

The plan for flood mitigation on Shoal Creek will be the diversion of floodwater by means of two 14-foot diameter tunnels with intakes located at Pease Park near 19th Street and at the Northwest Park Detention Facility near the inlet weir. The 19th Street tunnel will divert floodwater from Shoal Creek to Town Lake and the Northwest Park tunnel will divert floodwater to Lake Austin. An improved channel will extend from Foster Lane to the downstream side of U.S. Highway 183 and then from the upstream side of U.S. Highway 183 to the Missouri-Pacific Railroad bridge. The plan includes the construction of two 11-foot diameter conduits through the embankment of U.S. Highway 183.

The plan for the reduction of flooding on Hancock Creek will be an improved channel from about 700 feet downstream from Hancock Drive to Houston Street with new bridge structures at Hancock Drive, North Loop Boulevard, and Houston Street. A new box culvert will be constructed under Burnet Road and the shopping center that is located over Hancock Creek. Construction of this culvert will be by cut and cover between the shopping center buildings.

19TH STREET TUNNEL

Plan. The proposed tunnel will be a 14-foot diameter conduit with a horizontal length of about 5,200 feet. The tunnel intake will be on the right bank of Shoal Creek at Station 94+30 near 19th Street. It will remove 3,800 cfs from the Standard Project Flood (SPF) runoff above the intake and bypass 23,400 cfs to the downstream creek. The tunnel outfall will be about 180-feet southwest of the Missouri-Pacific Railroad near Orchard and Pressler Streets and about 800-feet from the north bank of Town Lake. At the tunnel outlet portal will be a concrete hydraulic-jump type stilling basin discharging into a riprap lined outlet channel which will transition to an earth lined trapezoidal channel. The outlet channel will extend through the bank of Town Lake and flows will be conveyed under Lake Austin Boulevard by a new multiple box culvert.

Intake. The details for the 19th Street tunnel inlet are shown on plates D-17 through D-19. The tunnel intake control will consist of an ogee weir with a crest at elevation 482.0 NGVD and crest width of 68 feet with three 2-foot wide piers to support the trash racks and roof. The weir height will be 4.0 feet with a design head of 6.0 feet, therefore P/Hd = 0.67. The weir will have a vertical upstream face and the weir profile is based on HDC 111-1 and 111-2/1. The rating curve for the weir is based on HDC 122-1/2 with type 1 abutments and type 2 piers. The man-proof trash racks will be placed about 12 feet upstream from the upstream face of the weir and will have a net flowage area of at least 65 percent of the gross area. The bars will have an L/T of about 10 with rounded corners such that kt = 0.8 based on HDC 010-7. The downstream quadrant of the weir will transition to the outlet shaft at elevation 462.0 NGVD by a 14-foot radius.

The downstream quadrant of the weir will intersect the apron at the weir abutment walls at elevation 467.0 NGVD. The apron will not become the control during the passage of the design discharge. The apron slopes from each abutment wall on a 1 vertical to 2.22 horizontal slope and will transition to the vertical at the 14-foot by 14-foot square outlet shaft through a 3 foot radius. Below elevation 462.0 NGVD will be a 14-foot by 14-foot square 90 degree circular bend with a centerline radius of 21.0 feet and the invert at elevation 434.0 NGVD. At the downstream end of the bend will be a 14- foot by 14-foot square spacer with a horizontal length of 14 feet. The square spacer is then reduced to the 14-foot tunnel diameter by a linear transition with a horizontal length of about 16 feet.

The intake structure will be set into the right bank of Shoal Creek at Station 94+30. The approach to the intake will be a channel with a concrete apron at about elevation 478.0 NGVD, that varies from 40 to 90 feet in width and extends upstream to Station 95+20 and downstream to the upstream toe of the channel dam at Station 93+35. The approach channel conforms very closely to the natural channel dimensions at the inlet site and will have concrete side slopes of 1 vertical on 1 horizontal on the right bank of the creek up to elevation 492.0 and grass-lined side slopes of 1 vertical on 3 horizontal on the left bank of the creek up to about elevation 484.0. Storm flows will be diverted to the tunnel by an earth embankment channel dam with concrete plating. The channel dam centerline will be at Station 93+00. The channel dam will have crest length of about 210 feet and a crest width of 10 feet. The crest will be at elevation 488.0 NGVD and the side slopes will be on 1 vertical to 3 horizontal upstream and downstream of the crest. Low flows up to 60 cfs will pass through the dam by an uncontrolled 42-inch diameter conduit before stormwater is diverted to the tunnel. When the channel discharge exceeds 60 cfs, the tunnel inlet weir will be overtopped at elevation 482.0 NGVD and the tunnel will divert stormwater to Town Lake. When the channel discharge reaches approximately 3,600 cfs, which is about a 2-year frequency discharge, then the tunnel will have reached its near maximum capacity and will divert approximately 3,500 cfs to Town Lake, while about 100 cfs will be bypassed to the downstream channel through the 42-inch conduit. When the channel discharge exceeds 3,600 cfs, the channel dam will be overtopped allowing higher flows to pass downstream. The tunnel effectively reduces the peak discharges to the downstream channel by 3,500

cfs for the 2-year discharge and up to 3,800 cfs for the SPF discharge. The downstream natural channel bottom and side slopes will be protected by riprap for a distance of 50 feet from the downstream toe of the dam up to elevation 490.0 NGVD.

Conduit. The horizontal portion of the tunnel will be constructed by a tunnel boring machine to a diameter of about 16 feet for a 14-foot diameter conduit with a 1-foot thick liner. The liner will be either cast in place concrete or precast concrete segments. Tunnel boring will proceed from the outfall to the intake on a slope of 0.001 ft/ft. There will be no bends in the horizontal portion of the conduit. Cut and cover construction of the conduit at the downstream end will be required for a length of 100 to 150 feet due to the overburden being less than 10 feet in depth at that location. A steep bank is located immediately downstream from the Missouri-Pacific Railroad at about 150 feet from the conduit outlet portal. The overburden depth at the railroad tracks is about 27 feet above the top of the conduit and increases to about 35 feet at a distance of about 600 feet upstream from the railroad tracks. This portion of the conduit may also be constructed by the cut-and-cover method or by convention tunnel mining methods. No adverse conditions are expected to prevent the use of the tunnel boring machine for construction of the remainder of the conduit.

Outfall. The details of the outfall are shown on plates D-20 through D-22. The conduit outlet portal invert will be at elevation 429.0 NGVD. The conduit will discharge into a concrete U-frame type stilling basin. The chute and stilling basin are designed in accordance with WESHS Memorandum for Record, Subject: Spillway Stilling Basin, Hydraulic Jump Type, dated 25 June 1974. The chute and stilling basin are designed for maximum velocity and discharge based on smooth pipe flow, as set forth in EM 1110-2-1602, dated 15 October 1980, with the tunnel inlet head based on the standard project flood water surface elevation of 497.0 NGVD. The stilling basin design discharge and outlet portal velocity are respectively, 4,950 cfs and 32.1 ft/sec. The Froude number at the outlet portal for the design discharge is 1.52 and the Froude number at the toe of the transition chute is 5.04. A range of tunnel discharges from 1,000 cfs to 3,800 cfs were analyzed with the resulting Froude numbers ranging from 10.4 to 5.2. Satisfactory basin performance was indicated for all tunnel discharges.

An analysis of slug flow or large air bubbles moving through the tunnel was performed. Slug flow can cause adverse wave action in the stilling basin and outlet channel and usually occurs in a flow transition zone between partly full and full flow. The full flow tunnel discharge was computed to be about 1,250 cfs. Computation of flow profiles within the conduit for a range of discharges less than 1,250 cfs and computation of the critical slope indicates that flow in the conduit will remain sub-critical until full flow is obtained. Flood discharges on Shoal Creek are known to peak very rapidly so the flow transition zone where slug flow may occur will be of very short duration, therefore, flow instabilities within the tunnel or the stilling basin will not be expected. The outlet structure consists of a 60-foot parabolic chute, and a stilling basin 64 feet in length, 30 feet in width with vertical training walls. The basin

floor will be at elevation 411.0 NGVD. The stilling basin will have two rows of baffle blocks 3 feet 6 inches high by 3 feet wide, spaced 3 feet apart. The end sill height will be 2.0 feet and the top of the training walls will be at elevation 434.0 NGVD. The training wall height is based on a coincident pool elevation on Town Lake of 433.5 NGVD for the 100-year flood on Shoal Creek. The minimum tailwater elevation at the end sill of the stilling basin for the design discharge of 4,950 cfs will be 429.4 NGVD, and is based on the Town Lake normal pool elevation of 428.0 NGVD plus outlet channel losses.

The outlet channel will consist of a preformed scour hole in the form of a riprap lined trapezoidal channel with wraparound side slopes of 1 vertical on 3 horizontal. The invert of the outlet channel slopes up on a 1 vertical to 10 horizontal slope a total distance of 70 feet from the end sill of the stilling basin up to elevation 418.0 NGVD. The outlet channel bottom width will be 36 feet at the end sill of the stilling basin and will transition to 65 foot bottom width 70 feet downstream. The outlet channel will continue downstream with a 65 foot bottom width, 1 vertical to 3 horizontal grass-lined side slopes with a level invert at elevation 418.0 NGVD. The grass-lined outlet channel will transition upstream and downstream of a new multiple box culvert under Lake Austin Boulevard for a distance of 50 feet on either side of the street. The multiple box culvert will be six 10-foot by 10-foot concrete box culverts 60 feet in length. The 65 foot grass-lined open channel invert elevation at Town Lake will be 418.0 NGVD. The multiple box culvert at Lake Austin Boulevard will be of sufficient size to limit flow velocity to 7 feet per second in the channel at the design discharge.

Rating. Friction loss for flow of water in the tunnel was computed with resistance coefficient set forth in USAWES HDC sheet 224-1 and Chart 224-1 for ks = 0.002 feet. Losses for bends and diffusers are based on curves found in Internal Flow Systems by D. S. Miller. The boundary friction losses for the tunnel liner are based on the Darcy-Weisbach equation with the Darcy friction factor for ks = 0.002 feet as shown in HDC 224-1. For a maximum inlet water surface elevation of 497.0 NGVD the discharge capacity is 3,800 cfs. If a precast tunnel liner is used then the misalignment at each joint of the liner should be less than 1/4 inch to minimize expansion and contraction losses. The tunnel has been rated for a capacity discharge of 3,800 cfs and a rating curve for the water surface at the tunnel intake is shown on plate D-23. This rating represents the combined effects of the tunnel inlet weir, the tunnel under pressure flow, and the channel dam. The channel dam has been rated for weir flow using the HEC-2 backwater program. There will be no induced damages resulting from the proposed tunnel inlet structures.

Sedimentation. The approach channel at the intake structure has been designed to be a stable channel bottom and maintain a consistent depth of flow at the approach to the tunnel inlet weir. It also serves as a sediment settling basin and the concrete apron provides for ease of sediment removal. Since little or no sedimentation data collection has been done, a complete detailed sediment analysis is not possible. However, field investigations have revealed that the rocky natural streambed shows very little if any, effects of scour or deposition

following major flows. The settling basin is expected to trap larger sediment particles which would be abrasive to the conduit invert. In addition, because of the highly developed nature of the watershed, sources of sediment from local inflow are expected to be minimal. Removal of sediment from the approach channel and inspection of the outlet channel depth on an annual basis should be adequate.

Care of Water During Construction. The work area at the 19th Street tunnel will be protected by a temporary cofferdam high enough to divert all stream flow for a 100-year flood plus 4 feet freeboard to elevation 498.0 NGVD. The downstream channel weir will be constructed following completion of the tunnel intake and the approach channel. Seepage water or other liquids collected at the outfall during construction of the conduit, stilling basin, or the outlet channel will be treated, if necessary, to remove all undesirable contaminates that may be harmful to humans and/or the environment if it is to be released to Town Lake. The outlet channel will be constructed following completion of the stilling basin.

NORTHWEST PARK TUNNEL

Plan. The proposed tunnel will be a 14-foot diameter conduit with a horizontal length of about 14,030 feet. The tunnel intake will be on the right bank of Shoal Creek opposite the inlet weir of the Northwest Park detention ponds at river Station 397+15. It will remove 4,400 cfs from the Standard Project Flood runoff above the intake and will bypass 16,360 cfs to the downstream creek. The tunnel outfall will be on the left bank of the Colorado River, also known as Lake Austin, about 1,800 feet downstream from the confluence of Bull Creek and the Colorado River. At the tunnel outlet portal will be a concrete hydraulic-jump type stilling basin that discharges into a riprap lined outlet channel. The outlet channel will be about 200 feet in length from the end sill of the stilling basin to Lake Austin.

Intake. The details for the Northwest Park Tunnel inlet are shown on plates D-24 through D-29. The tunnel intake control will consist of an ogee weir with a crest at elevation 671.0 NGVD and crest width of 110 feet with five 2 feet wide piers to support the trash racks and roof. The weir height will be 4.0 feet with a design head of 5.0 feet, such that P/Hd = 0.80. The weir will have a vertical upstream face and the weir profile is based on HDC 111-1 and 111-2/1. The rating curve for the weir is based on HDC 122-1/2 with type 1 abutments and type 2 piers. The man-proof trash racks will be placed about 10 feet upstream from the upstream face of the weir and will have a net flowage area of at least 65 percent of the gross area. The bars will have an L/T of about 10 with rounded corners such that kt = 0.8 based on HDC 010-7. The downstream quadrant of the weir will intersect the apron at about elevation 660.0 to 661.1 NGVD. The apron will not become the control during the passage of the design discharge. A bucket with a 10-foot radius will form the transition from weir to apron. The transition from the apron to the vertical riser will be a 14-foot radius curve. The top of the vertical riser will be 14 feet by 14 feet square and will be reduced by a linear transition to a 14 foot

diameter in vertical distance of about 16 feet. Below this transition will be a 14 foot diameter spacer and a circular bend with a centerline radius of 21.0 feet with invert at elevation 588.0 NGVD at the downstream end of the bend. The approach to the intake will consist of a U-shaped channel formed by the existing vertical wall of the Northwest Park detention pond inlet weir on the east side of Shoal Creek and a new vertical concrete training wall to elevation 681.0 NGVD on the west side of the creek. The approach channel will have a bottom width of 72 feet and there will be a concrete apron at about elevation 667.0 feet NGVD in front of the tunnel intake weir which will extend upstream to Station 398+55. The approach channel will have an earth bottom as existing from Station 398+55 to Station 400+38. The channel downstream from the tunnel intake will be a U-shaped concrete channel 60 feet wide and 100 feet in length and will be partially blocked by an ogee weir with crest at elevation 676.3 feet NGVD. The weir will have four rectangular openings 4.0 feet in height and 7.5 feet in width. The weir openings will extend vertically from elevation 666.8 NGVD at the channel invert up to elevation 670.8 NGVD. The openings are designed to allow flows up to 1,000 cfs to bypass to the downstream creek before being diverted to the tunnel. This design will allow possible water borne pollutants from initial storm runoff upstream to be bypassed to the downstream creek rather than to Lake Austin through the tunnel. The tailwater level for 1,000 cfs at the weir is 670.8 NGVD. When the channel discharge exceeds 1,000 cfs, the water surface at the tunnel inlet weir will exceed elevation 671.0 and the channel weir will become effective in diverting floodwater to the tunnel. When channel discharge reaches approximately 6,100 cfs, which is about a 2-year frequency discharge, then the tunnel will have reached its near maximum capacity and will divert approximately 4,300 cfs to Lake Austin. The channel water surface elevation at the tunnel inlet corresponding to 6,100 cfs will be about 676.2 NGVD, and the discharge that will bypass to the downstream channel through the opening in the channel weir will be about 1,800 cfs. When the channel discharge exceeds 6,100 cfs, then both the channel weir and the Northwest Park Detention Pond weir are overtopped. As the detention pond is filling, it serves to reduce the peak discharge to the downstream channel up to its maximum storage capacity while the tunnel reduces peak discharges to the downstream channel for all frequency floods above 1,000 cfs. The channel weir will be located 50 feet upstream from the downstream end of the concrete U-shaped channel to provide a stilling basin for the flow over the weir. The channel bottom will have riprap protection for a distance of 50 feet downstream from the end of the 60 foot concrete channel.

Conduit. The horizontal portion of the tunnel will be bored by a tunnel boring machine to a diameter of about 16 feet for a 14 foot diameter conduit with a 1 foot thick liner. The liner will be either cast in place concrete or precast concrete segments. Tunnel boring will proceed from the outfall to the intake on a slope of 0.00675 ft/ft. There will be no bends in the horizontal portion of the conduit. There will be no relocation of existing roads due to the construction of the conduit, however, an access road to the outfall site will be required.

Outfall. The details of the outfall structure are shown on plates D-30 and D-31. The conduit outlet portal invert will be at elevation 493.5

NGVD. The conduit will discharge into a concrete U-frame type stilling basin. The chute and stilling basin are designed in accordance with WESHS Memorandum for Record, Subject: Spillway Stilling Basin, Hydraulic Jump Type, dated 25 June 1974. The chute and stilling basin are designed for maximum velocity and discharge based on smooth pipe flow, as set forth in EM 1110-2-1602, dated 15 October 1980, with the tunnel inlet head based on the standard project flood water surface elevation of 685.0 NGVD. The stilling basin design discharge and outlet portal velocity are respectively, 5,900 cfs and 38.4 ft/sec. The Froude number at the outlet portal for the design discharge is 1.81 and the Froude number at the toe of the transition chute is 5.49. A range of tunnel discharges from 1,000 cfs to 5,000 cfs were analyzed and the resulting Froude numbers ranged from 11.3 to 5.47. Satisfactory basin performance was indicated for all tunnel discharges. An analysis of slug flow or large air bubbles moving through the tunnel was performed. Slug flow can cause adverse wave action in the stilling basin and outlet channel and usually occurs in a flow transition zone between partly full and full flow. The full flow tunnel discharge was computed to be about 3,340 cfs. Computation of flow profiles within the conduit for a range of discharges less than 3,340 cfs indicates that open channel flow will exist and that flow depths will transition from subcritical to supercritical very rapidly at the tunnel inlet riser and remain supercritical to the outlet portal due to the tunnel invert slope of 0.00675 feet per foot. Flood discharges on Shoal Creek are known to peak very rapidly so the flow transition zone where slug flow may occur will be of very short duration, therefore, flow instabilities within the tunnel or the stilling basin will not be expected.

The outlet structure will consist of a 63-foot parabolic chute, and a stilling basin 75 feet in length, 30 feet in width with vertical training walls. The basin floor will be at elevation 471.0 NGVD. The stilling basin will have two rows of baffle blocks 3 feet 6 inches high by 3 feet wide, spaced 3 feet apart. The end sill height will be 2.0 feet, and the top of the training walls will be at elevation 495.0 NGVD. The training wall height is based on the Colorado River water surface elevation corresponding to a discharge of 100,000 cfs on the river. A coincident frequency analysis will be completed in the ongoing study. The minimum tailwater elevation at the end sill of the stilling basin for the design discharge of 5,900 cfs will be 492.7 NGVD, and is based on the Lake Austin normal pool elevation of 492.5 NGVD plus outlet channel losses.

The outlet channel will consist of a preformed scour hole in the form of a riprap lined trapezoidal channel with wraparound side slopes of 1 vertical to 3 horizontal. The invert of the outlet channel will slope up on a 1 vertical to 10 horizontal slope for a total distance of about 110 feet from the end sill of the stilling basin up to elevation 482.0 NGVD. The outlet channel invert beyond 110 feet from the end sill of the stilling basin will be at elevation 482.0 NGVD to the point of intersection with the bank slope of Lake Austin.

<u>Rating.</u> Friction loss for flow of water in the tunnel was computed with resistance coefficient set forth in USAWES HDC sheet 224-1 and Chart 224-1 for ks = 0.002 feet. Losses for bends and diffusers are based on curves

found in Internal Flow Systems by D. S. Miller. Computation of tunnel capacity and the boundary friction losses for the tunnel liner are based on the Darcy-Weisbach equation with the Darcy friction factor for ks = 0.002 feet as shown in HDC 224-1. The discharge capacity is 4,400 cfs for a maximum inlet water surface elevation of 685.0 NGVD. If a precast tunnel liner is used then the misalignment of each joint of the liner should be less than 1/4 inch to minimize expansion and contraction losses. The tunnel has been rated for a capacity discharge of 4,400 cfs and a rating curve for the water surface at the tunnel intake is shown on plate D-32. This rating curve represents the combined effect of the tunnel inlet weir, the tunnel under pressure flow, the channel weir, and the Northwest Park detention pond inlet weir. The rating for the detention pond inlet weir has not been corrected for submergence.

A split flow analysis may be required to sufficiently rate the system for the higher flows. Sufficient analysis has been performed to determine that for the 100-year, 500-year, the SPF floods, the level of flooding upstream from the tunnel inlet will not be increased by the proposed structures. The tunnel inlet has been designed such that the tunnel will reach near maximum capacity before the Northwest Park Detention pond goes into operation. Flow will not be routed into the park until a 2-year frequency flood has been reached. Design changes to the existing detention pond structures are not being proposed. This will have the effect of the ponds reducing the peak discharge for less frequent events than originally designed. It will also reduce the frequency of needed repairs to the park facilities as well as the loss or use of such facilities due to flooding.

Sedimentation. The approach channel at the tunnel intake structure has been designed to provide a stable and consistent depth of flow at the tunnel inlet weir and to harmonize as much as practical with existing structures and right-of-way limits. Flow velocities in the approach channel will be such that the approach channel would not be an effective settling basin for sediments. Since the approach weir to the tunnel intake is set 4 feet above the channel apron, larger sediment particles are expected to be carried downstream through the opening in the channel weir rather than carried into the tunnel intakes. This would not be needed since Shoal Creek has shown very little effects of scour or deposition following major flows. The only significant concerns regarding sedimentation are that sediment accumulation in the approach channel and near the channel weir should be removed if an average depth of sediments of 4 inches has been reached. The openings in the channel weir provide for an uninterrupted flow line in the approach channel and will have a self cleaning action. Removal of sediments and debris in the approach channel and at the channel weir on an annual basis should be adequate to ensure the required by-pass of low flows.

There is no risk of sediment accumulation in the conduit itself and the stilling basin is designed to be self cleaning. However, the outlet channel should be inspected on an annual basis to insure adequate depth is maintained.

Care of Water During Construction. The work area at the Northwest Park tunnel intake will be protected by a temporary cofferdam high enough to divert all stream flow for a 100-year flood plus 4 feet freeboard to elevation 687.0. The downstream channel weir will be constructed following completion of the tunnel intake and the concrete channel. Seepage water or other liquids collected at the outfall during construction of the conduit, stilling basin, or the outlet channel will be treated, if necessary, to remove all undesirable contaminates that may be harmful to humans and/or the environment if it is to be released to Lake Austin. The outlet channel will be constructed following completion of the stilling basin.

CHANNELIZATION ON SHOAL CREEK

An intermediate improved channel will be located from Station 405+70 to U.S. Highway 183. The channel is a grass-lined trapezoidal channel with side slopes 1 vertical on 3 horizontal. The bottom width varies from 35 to 50 feet. A 50-foot bottom width, grass-lined, trapezoidal channel with side slopes 1 vertical on 3 horizontal is located upstream of U.S. Highway to the Missouri-Pacific Railroad bridge. The plan includes two 11-foot conduits bored and jacked under U.S. Highway 183. The conduits bypass about 4,000 cfs from the area upstream of U.S. Highway 183 to the downstream channel, decreasing the existing flooding problem in the area upstream of the highway. The 11-foot diameter size was selected as the largest diameter which could be jacked underneath the roadway embankments, including the service roads, without raising the road. The channel downstream of U.S. Highway 183 follows the existing grade of Shoal Creek. A portion of the channel downstream of the two 11-foot conduits was deepened and transitions to accommodate the outfall flow line of the conduits. The Manning's roughness coefficients used for the channel was 0.035.

The water surface profiles in the area of the improved channel were computed assuming removal of the existing bridges and replacement with new bridges at a low steel elevation sufficient to pass the 100-year flood. Six (6) bridges required replacement based on this criteria.

CHANNELIZATION ON HANCOCK CREEK

An improved grass-lined trapezoidal channel with a 25-foot bottom width and 1 vertical on 3 horizontal side slopes will extend from Station 16+00 upstream to Station 20+50. A transition from the natural channel to the improved trapezoidal channel will extend from Station 15+45 to Station 16+00. The improved grass-lined channel will transition to an improved concrete lined U-frame channel from Station 20+50 to Station 21+30. This 80 foot transition will have riprap side slopes for 40 feet on the downstream half and concrete side slopes for 40 feet on the upstream half. The transition will have a riprap lined channel bottom for the entire 80 foot length. An improved concrete lined U-frame channel will extend from Station 21+30 to the downstream side of Hancock Drive at Station 22+50. It will be 50 feet wide with vertical side slopes. Flows will be conveyed under Hancock Drive by a concrete multiple box culvert consisting of three

existing 8 foot by 8 foot boxes and the addition of three new 8 foot by 8 foot boxes adjacent to the existing boxes. Upstream of Hancock Drive from Station 23+00 to the downstream end of the culvert under the shopping center at Station 26+50 will be a new concrete lined U-frame channel with a 50 foot width and vertical side slopes.

The existing culvert under the shopping center and Burnet Road consists of four 8 foot by 8 foot concrete boxes at the upstream end which transitions to two concrete boxes 7 feet high by 12 feet wide. This culvert extends from Station 26+50 to Station 31+00. One building located directly above the existing culvert and another building 19 feet from it combine to impede overland flow from 340 feet to the left of the flow line to 530 feet to the right of the flow line. Capacity of the existing culvert before flooding of the shopping center buildings occurs will be about 2,300 cfs or about a 5-year frequency flood. Tunneling beneath the shopping center buildings to increase flow capacity was not considered due to the costs and risks involved. The space between the two shopping center buildings of about 19 feet is located about 150 feet to the left of the existing flow line and will be used to construct a new 10 foot by 10 foot concrete box culvert by the cut and cover method. The new box culvert will be about 570 feet in length and will have one 60 degree circular bend at about its midpoint. The invert elevation at each end of the new box culvert will match existing. The new culvert and the downstream channel improvements increase the flow capacity at the shopping center to about 4,700 cfs or about a 45-year frequency flood.

A new concrete lined U-frame channel with a 40 foot width and vertical side walls will extend from the upstream side of Burnet Road at Station 31+00 to the downstream side of Houston Street at Station 45+35. A new bridge at North Loop Boulevard will provide a 40 foot clear span over the new concrete channel. Flows will be conveyed under Houston Street by a new concrete multiple box culvert consisting of four 8 foot high by 10 foot wide boxes. A grass-lined transition channel from the upstream side of Houston Street at Station 45+85 to Station 46+85 will bring overbank flows from upstream into the improved channel. It will transition from a 42 foot bottom width with 1 vertical on 3 horizontal side slopes to the natural channel over a distance of 100 feet. Clearing and grubbing of the natural channel will be required upstream to Station 48+85. This plan is shown on plate D-33.

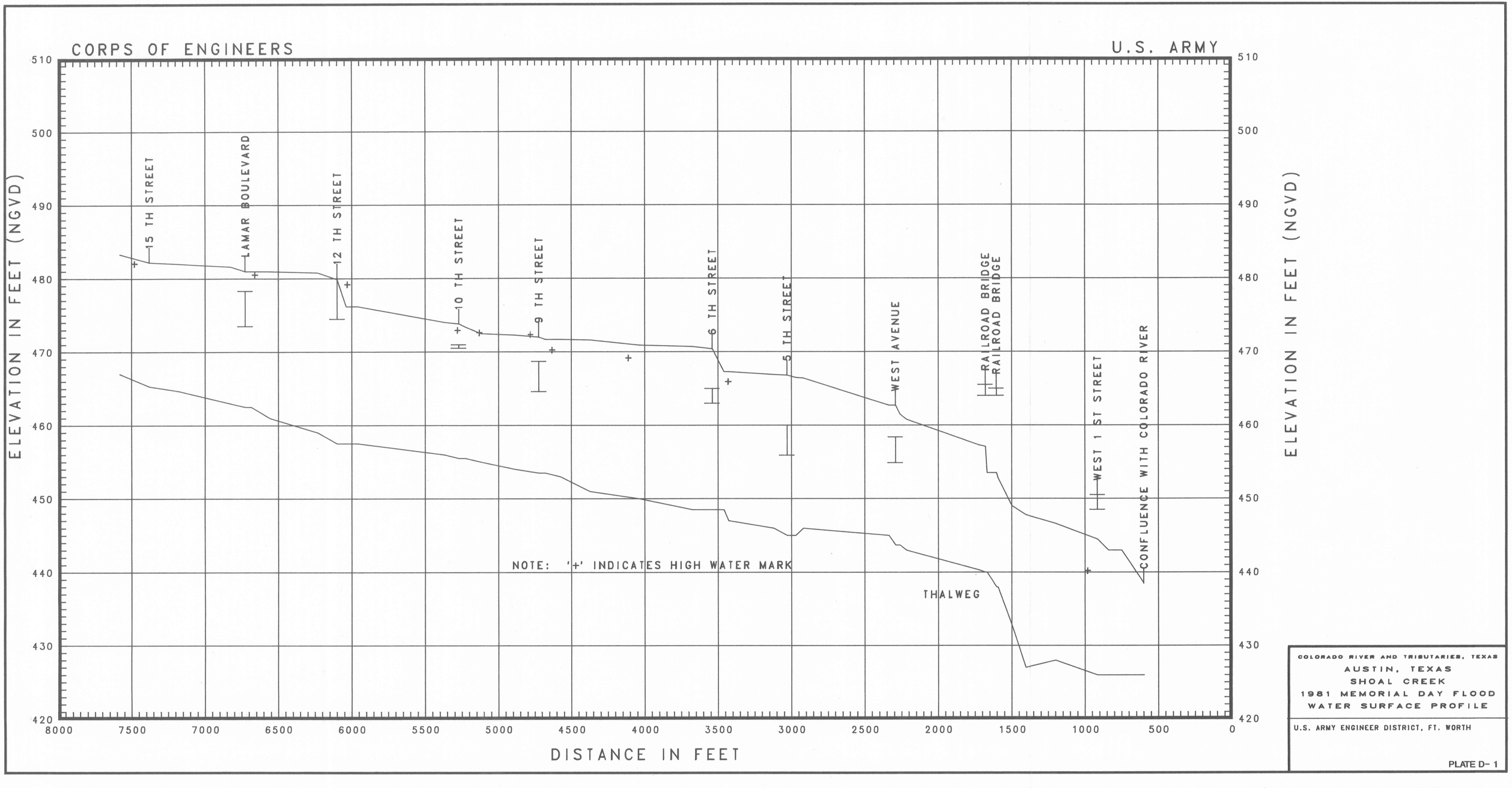
WATER SURFACE PROFILES

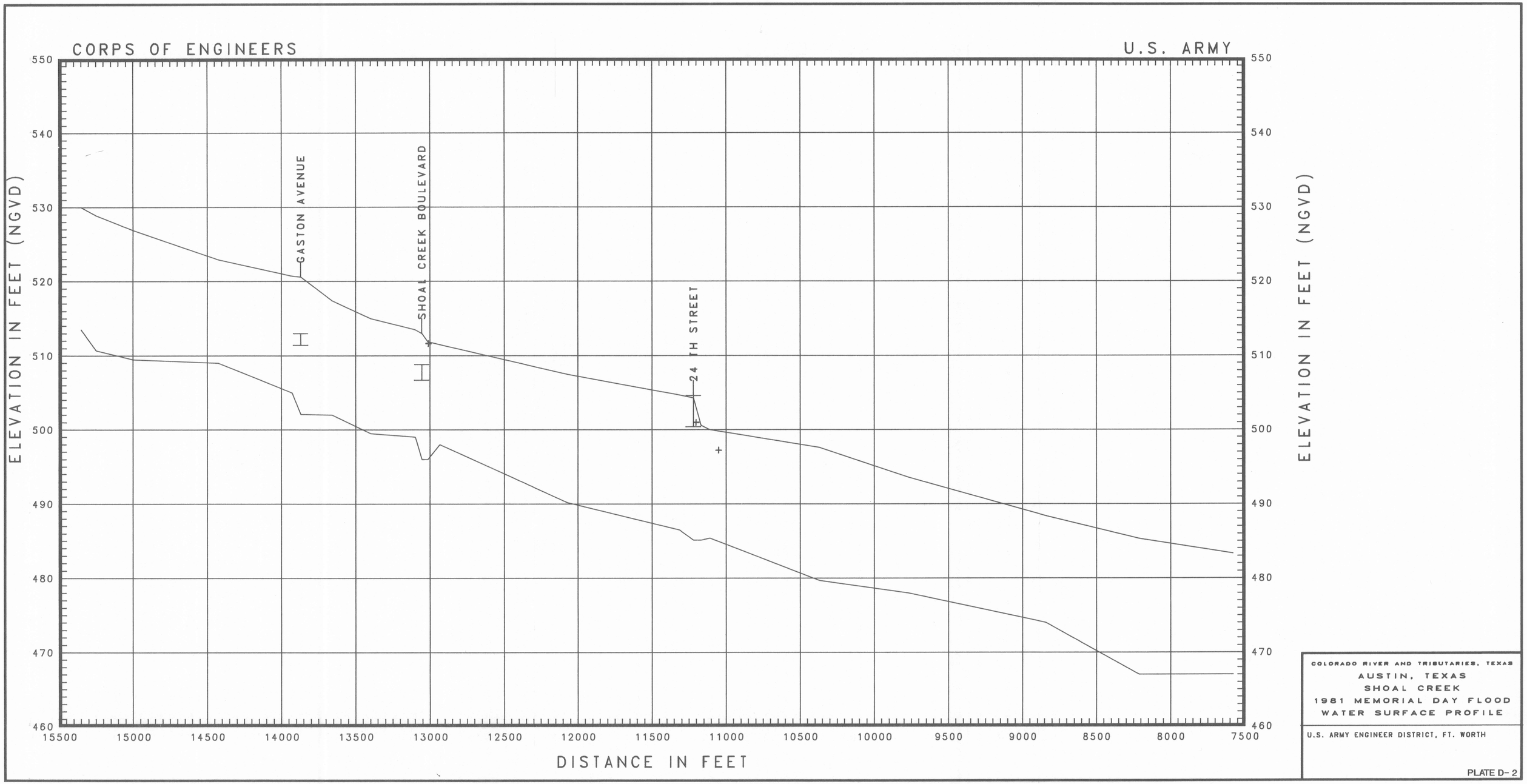
The selected plan water surface profiles for Shoal Creek and Hancock Creek are shown on plates D-34 through D-42. The Manning's roughness coefficients used for concrete channels was 0.016. Existing and improved flood plain delineations are shown on plates D-43 through D-53.

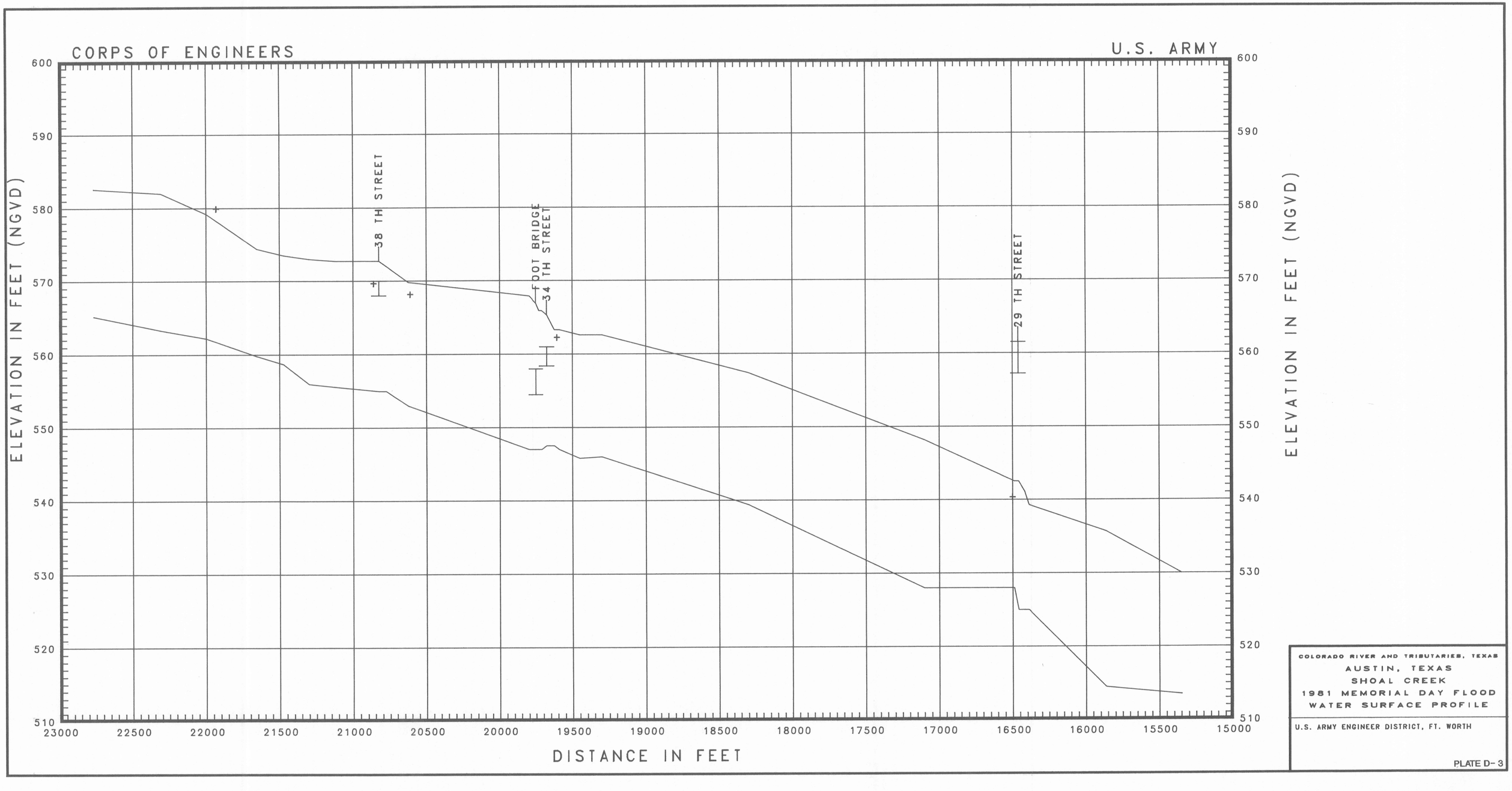
MODEL STUDIES

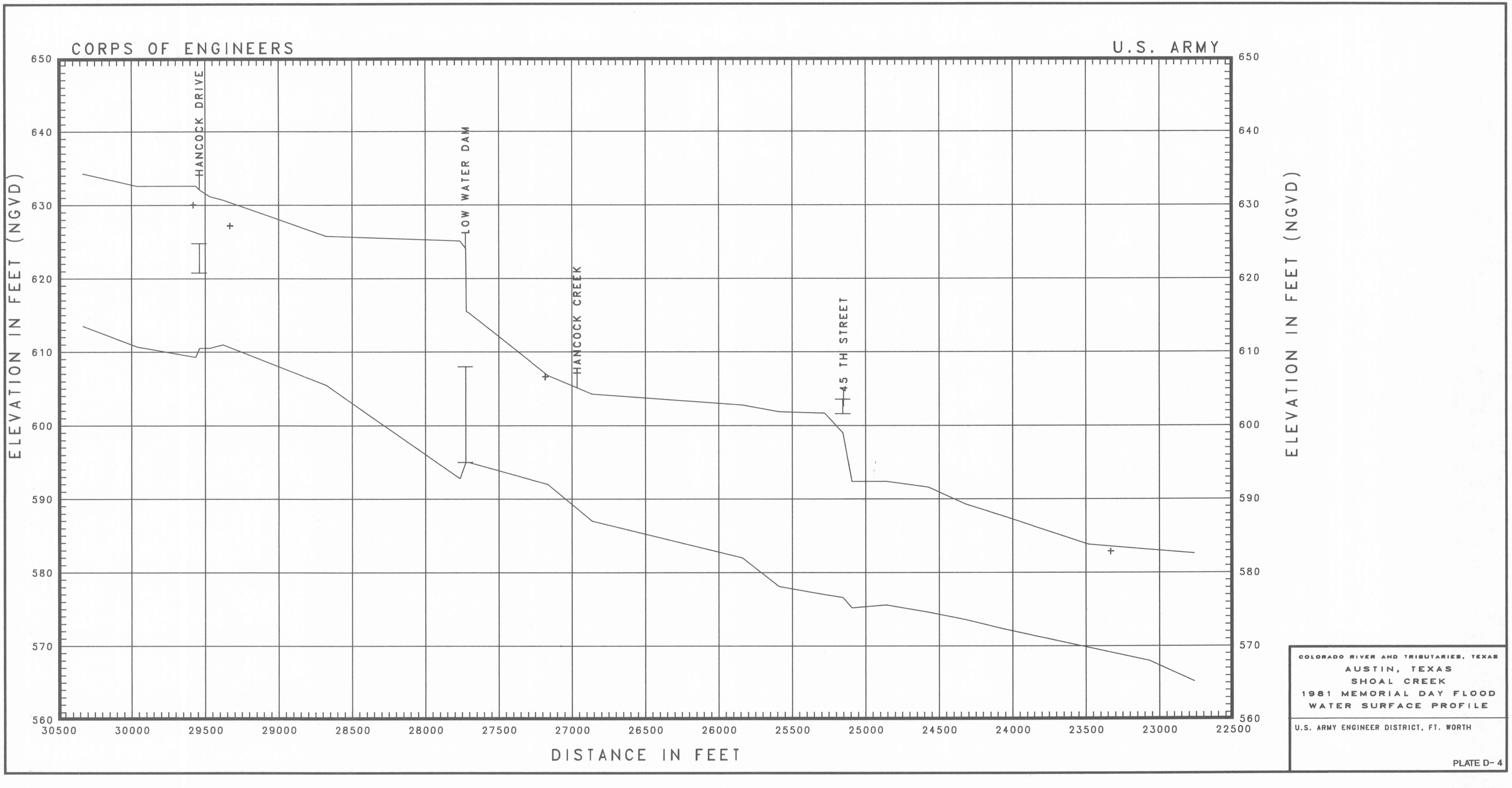
During detailed design of the project, physical model studies will be required to verify the satisfactory performance of the tunnel structures. The models will evaluate flow characteristics of the approach channels and

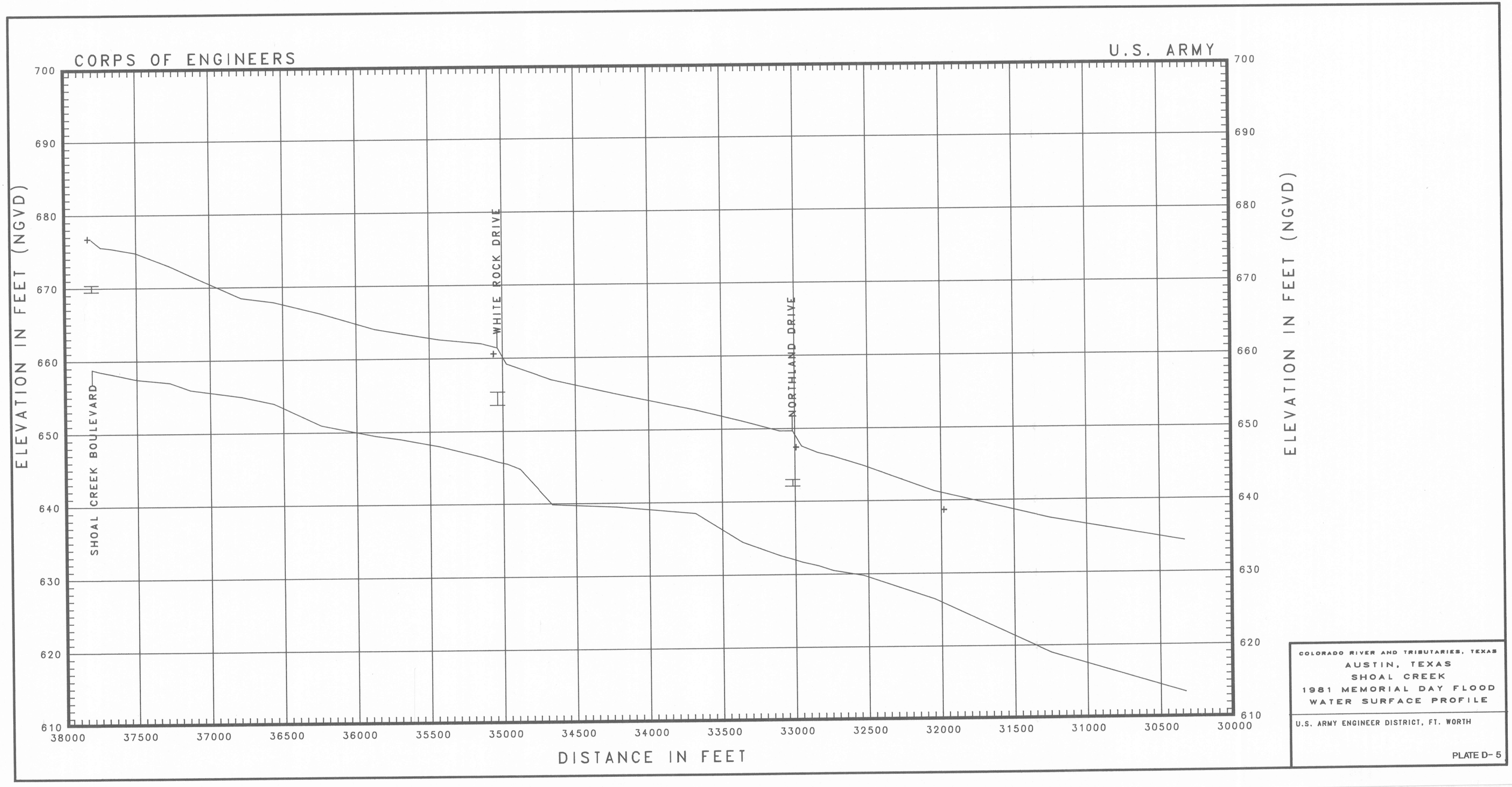
weirs, the flow conditions in the shaft section, tunnel capacities, and energy dissipation at the outfalls.

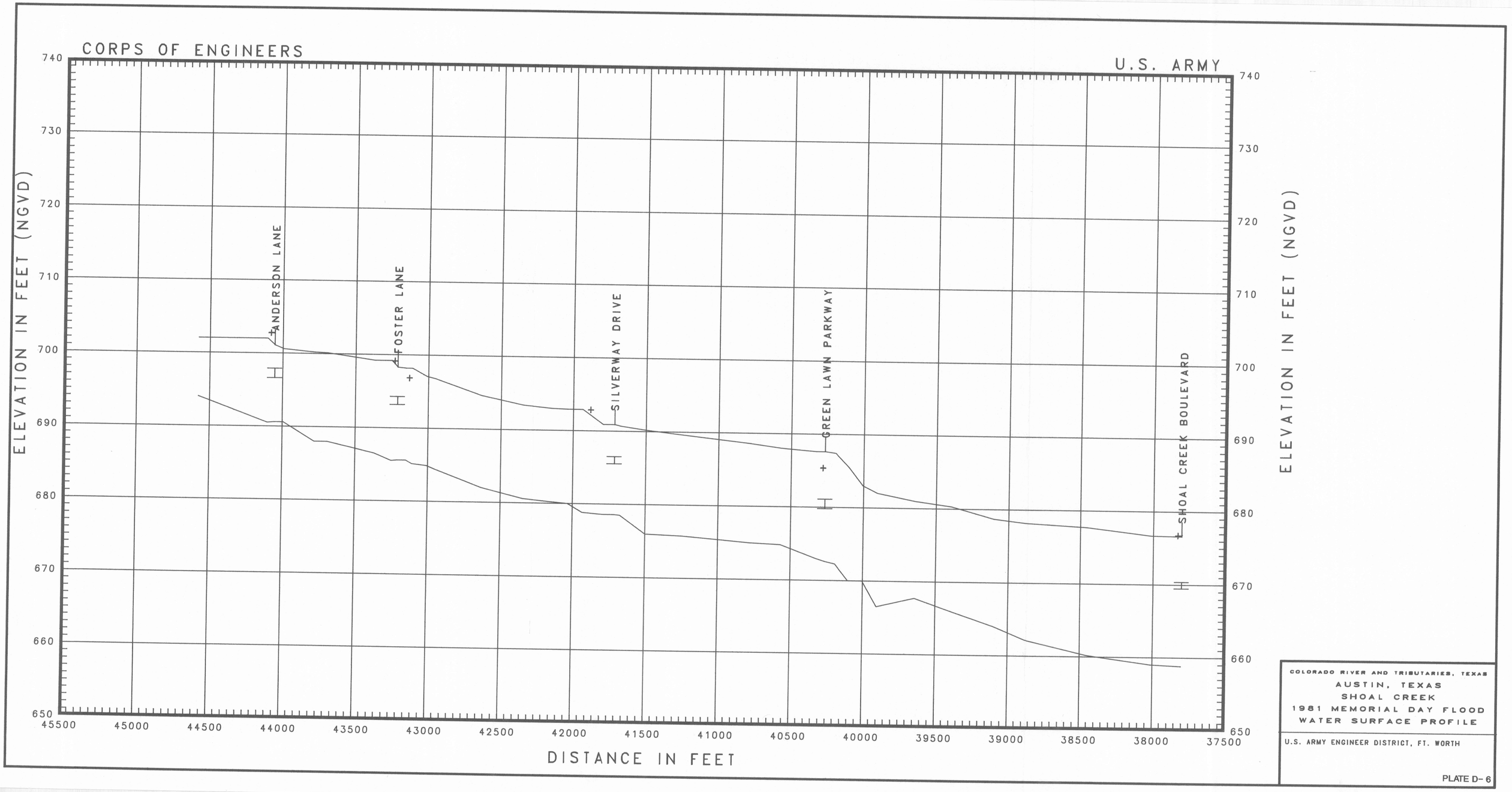

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
510
500
490
480
470
460
450
440
430
420
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
DISTANCE IN FEET
15 TH STREET
LAMAR BOULEVARD
12 TH STREET
10 TH STREET
9 TH STREET
6 TH STREET
5 TH STREET
WEST AVENUE
RAILROAD BRIDGE
RAILROAD BRIDGE
WEST 1 ST STREET
CONFLUENCE WITH COLORADO RIVER
NOTE: '+' INDICATES HIGH WATER MARK
THALWEG
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D- 1

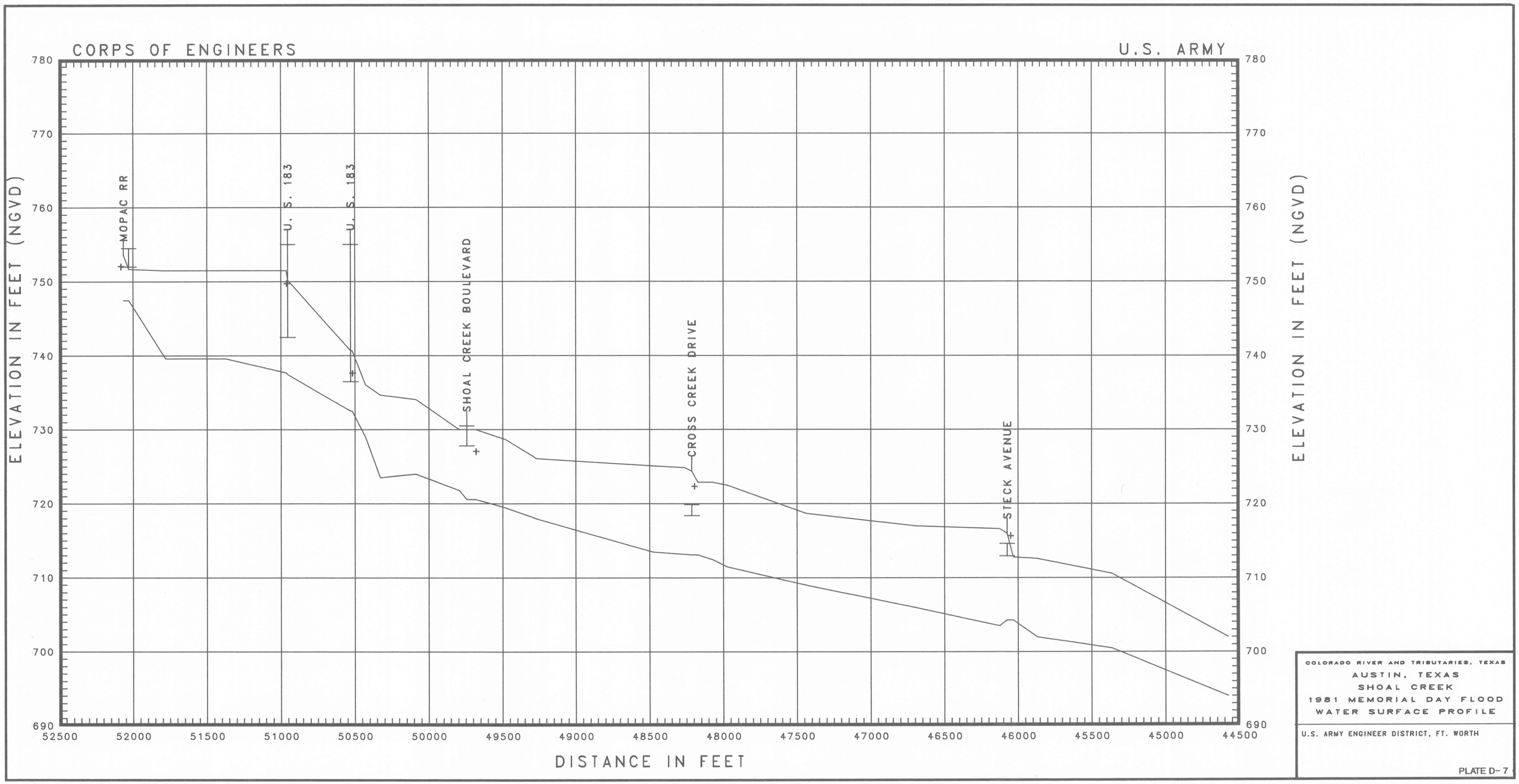

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
550
540
530
520
510
500
490
480
470
460
GASTON AVENUE
SHOAL CREEK BOULEVARD
24 TH STREET
15500
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-2

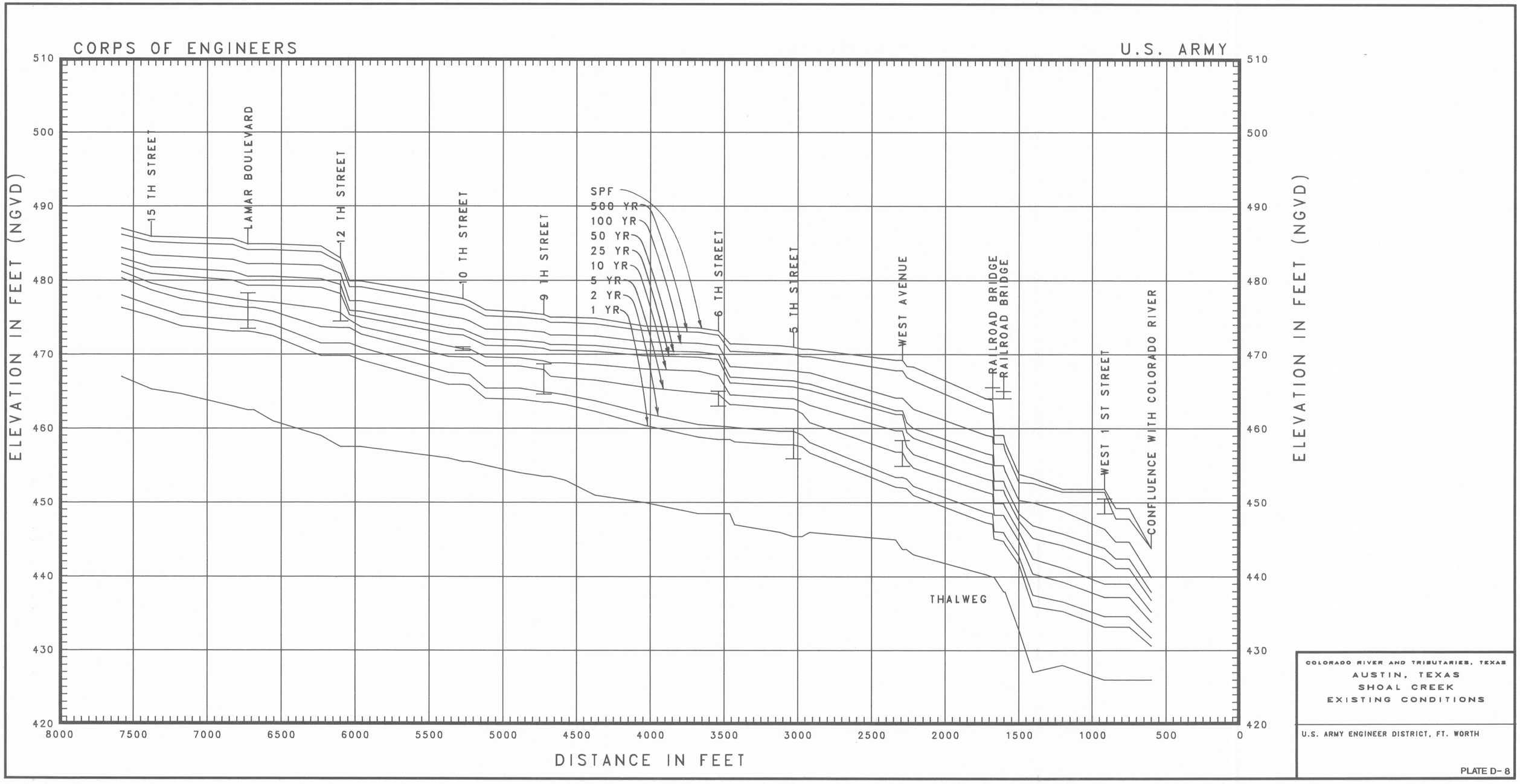

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
600
590
580
570
560
550
540
530
520
510
38 TH STREET
FOOT BRIDGE
34 TH STREET
29 TH STREET
23000
22500
22000
21500
21000
20500
20000
19500
19000
18500
18000
17500
17000
16500
16000
15500
15000
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-3


CORPS OF ENGINEERS
U.S. ARMY
HANCOCK DRIVE
LOW WATER DAM
HANCOCK CREEK
45 TH STREET
ELEVATION IN FEET (NGVD)
650
640
630
620
610
600
590
580
570
560
30500
30000
29500
29000
28500
28000
27500
27000
26500
26000
25500
25000
24500
24000
23500
23000
22500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-4


CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
700
690
680
670
660
650
640
630
620
610
SHOAL CREEK BOULEVARD
WHITE ROCK DRIVE
NORTHLAND DRIVE
38000
37500
37000
36500
36000
35500
35000
34500
34000
33500
33000
32500
32000
31500
31000
30500
30000
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-5


CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
740
730
720
710
700
690
680
670
660
650
ANDERSON LANE
FOSTER LANE
SILVERWAY DRIVE
GREEN LAWN PARKWAY
SHOAL CREEK BOULEVARD
45500
45000
44500
44000
43500
43000
42500
42000
41500
41000
40500
40000
39500
39000
38500
38000
37500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-6

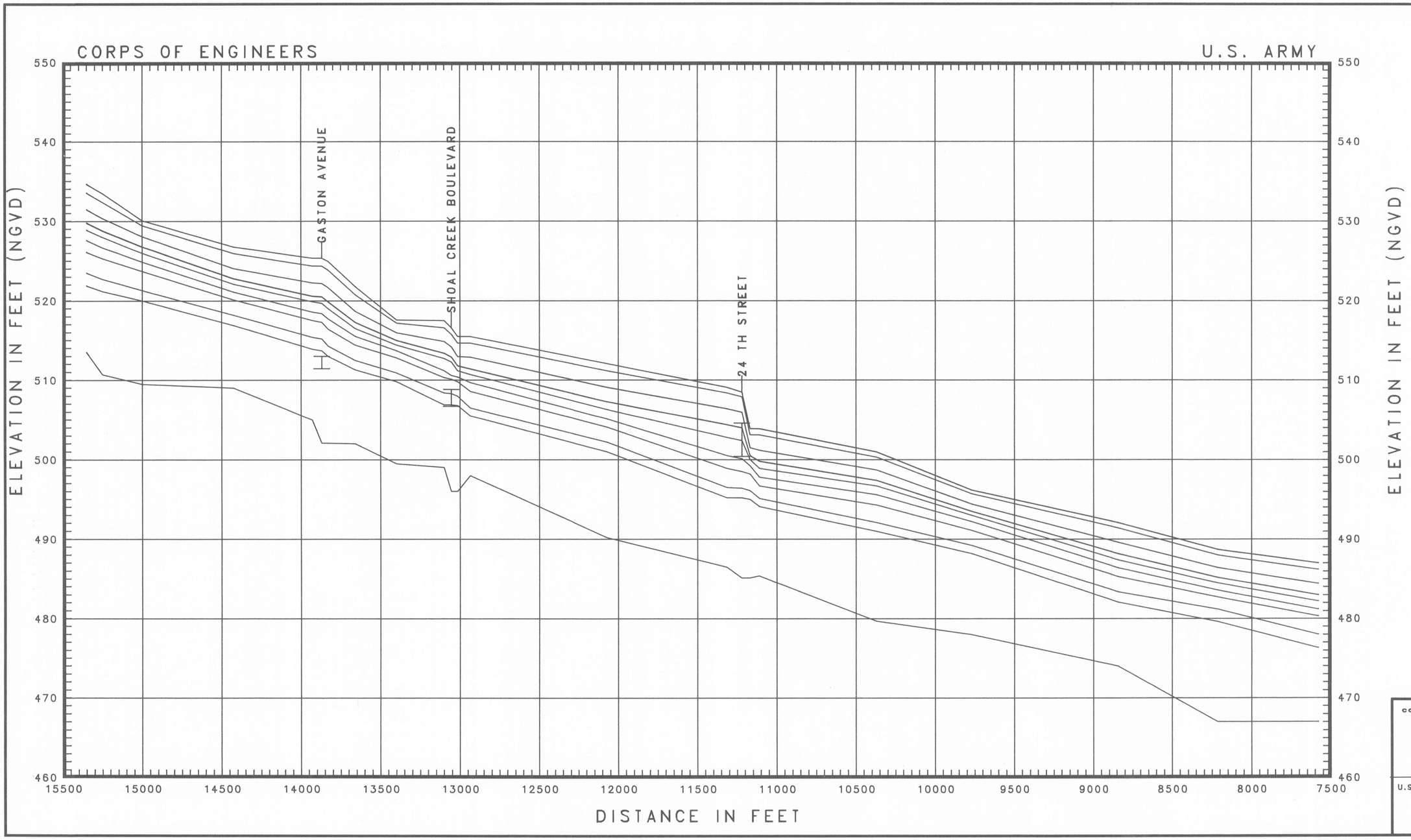

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
780
770
760
750
740
730
720
710
700
690
MOPAC RR
U. S. 183
U. S. 183
SHOAL CREEK BOULEVARD
CROSS CREEK DRIVE
STECK AVENUE
52500
52000
51500
51000
50500
50000
49500
49000
48500
48000
47500
47000
46500
46000
45500
45000
44500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
1981 MEMORIAL DAY FLOOD
WATER SURFACE PROFILE
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-7



COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-8

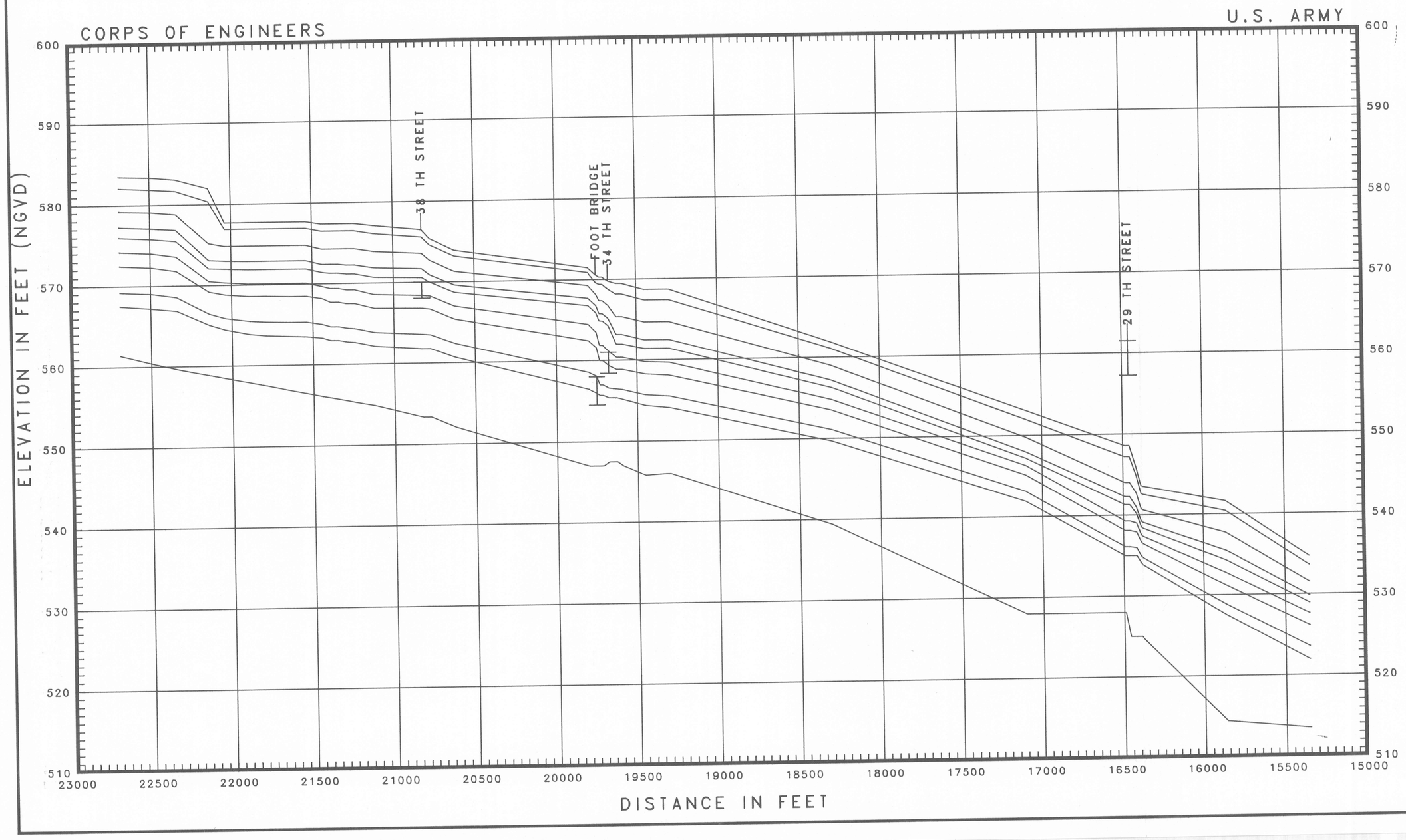


COLORADO RIVER AND TRIBUTARIES, TEXAS

AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

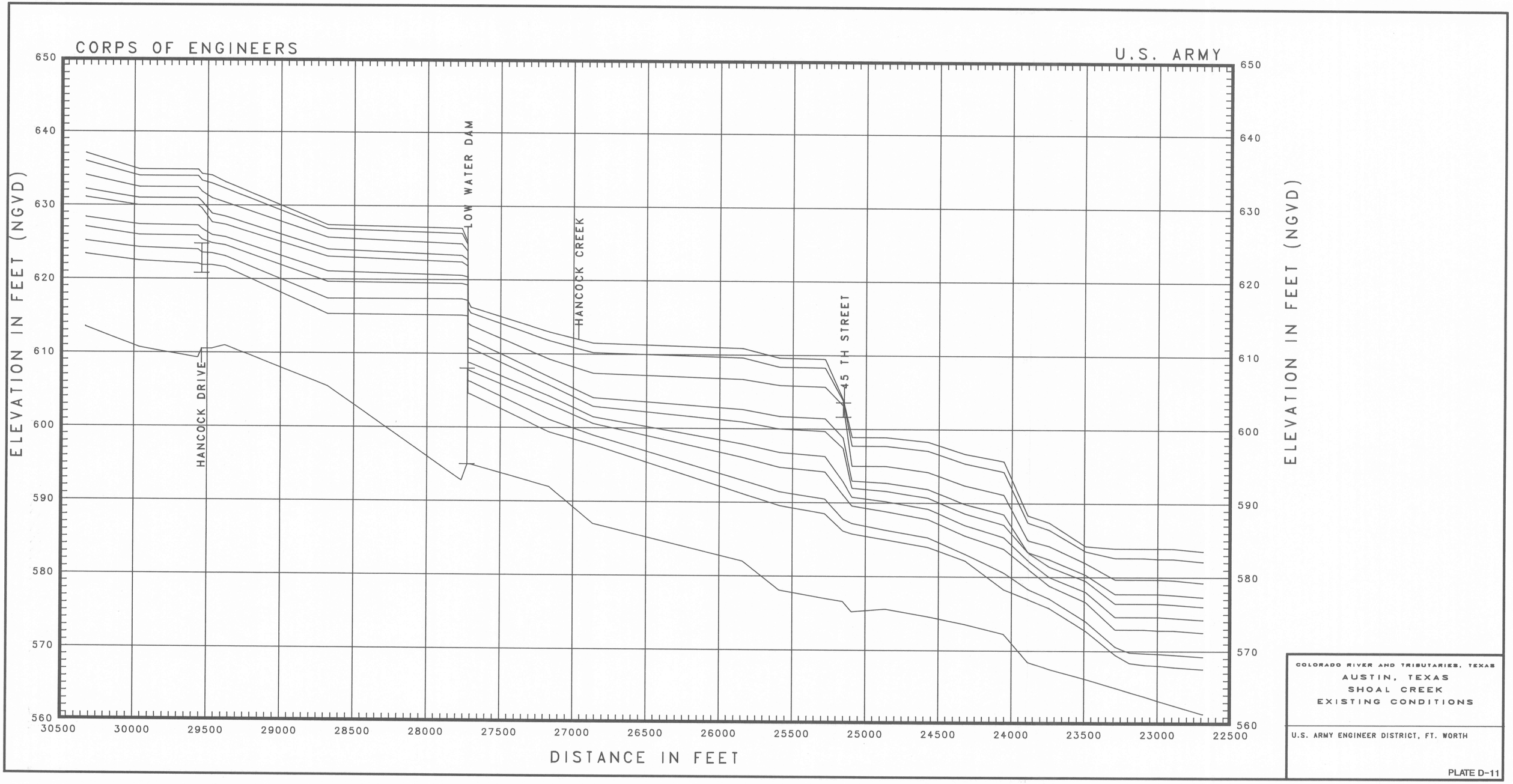
PLATE D-9

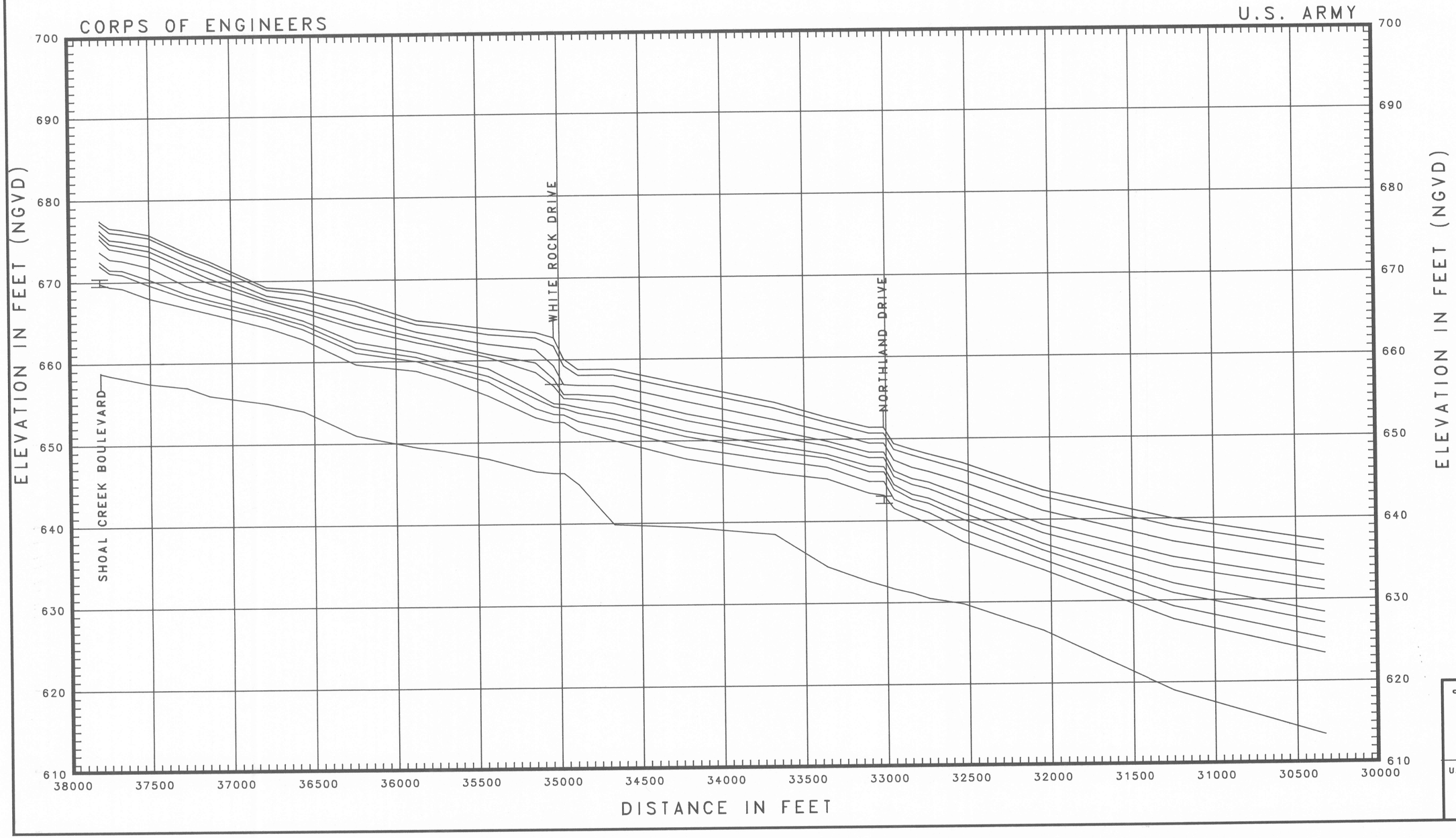


COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-10

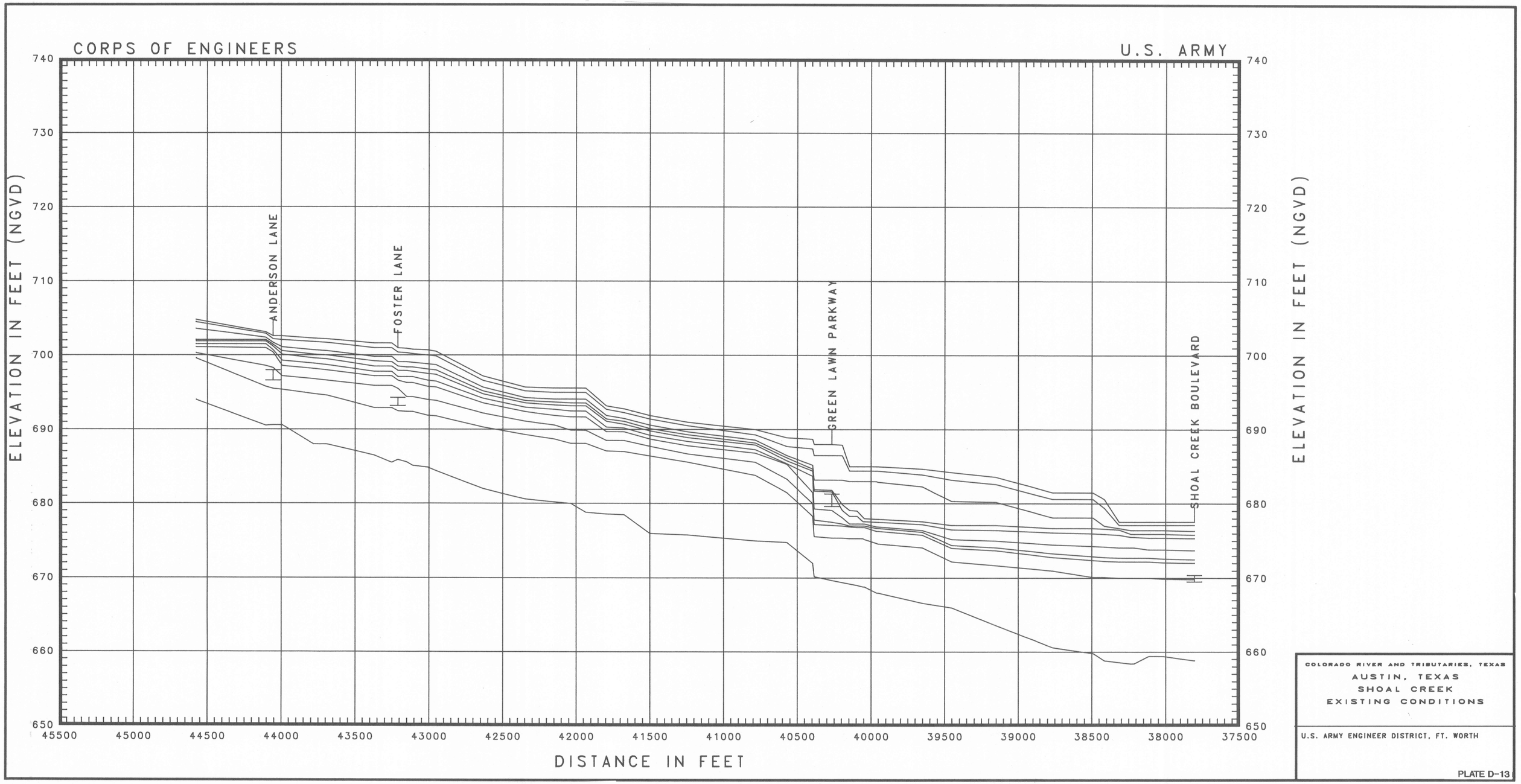

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
650
640
630
620
610
600
590
580
570
560
HANCOCK DRIVE
LOW WATER DAM
HANCOCK CREEK
45 TH STREET
30500
30000
29500
29000
28500
28000
27500
27000
26500
26000
25500
25000
24500
24000
23500
23000
22500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-11

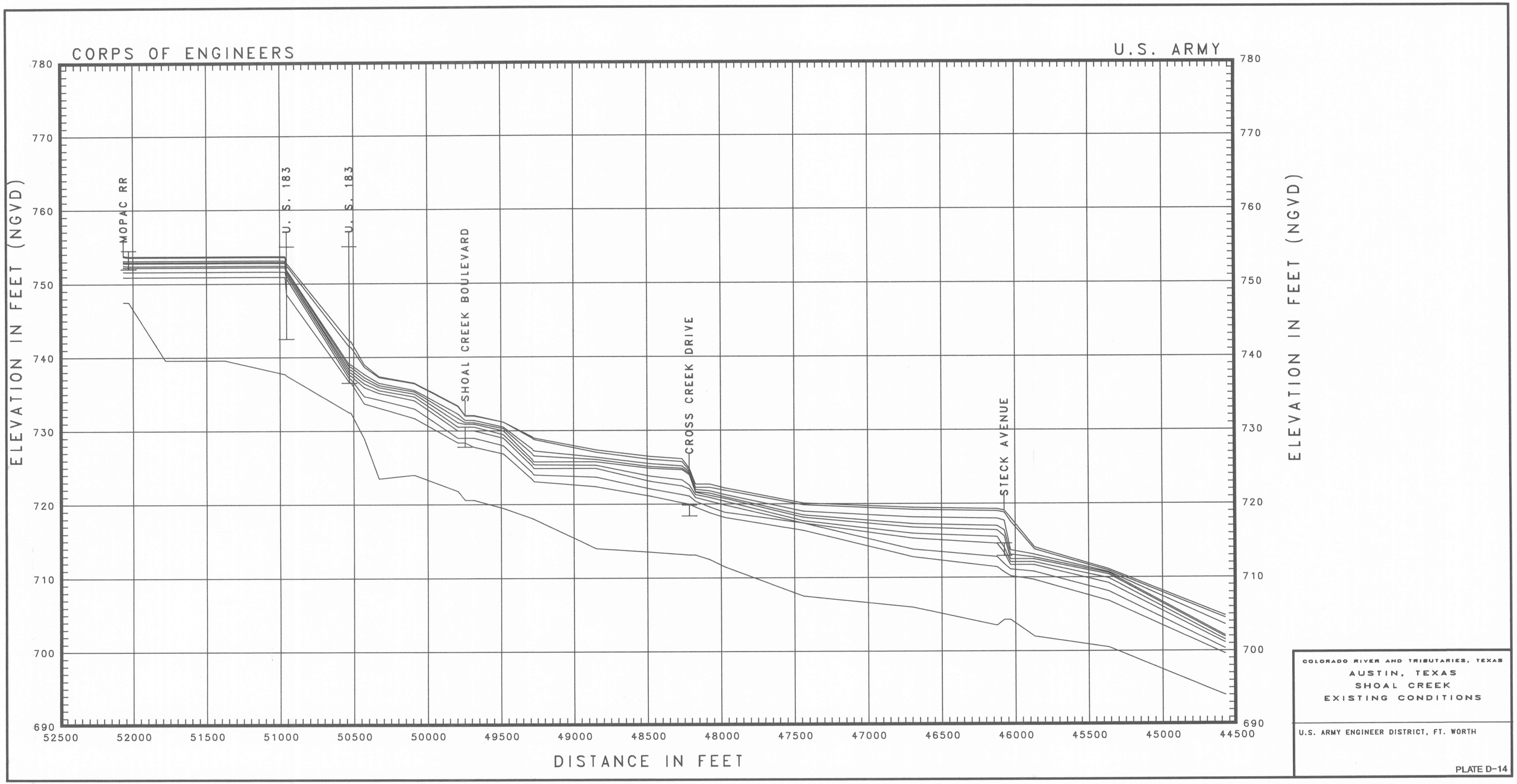


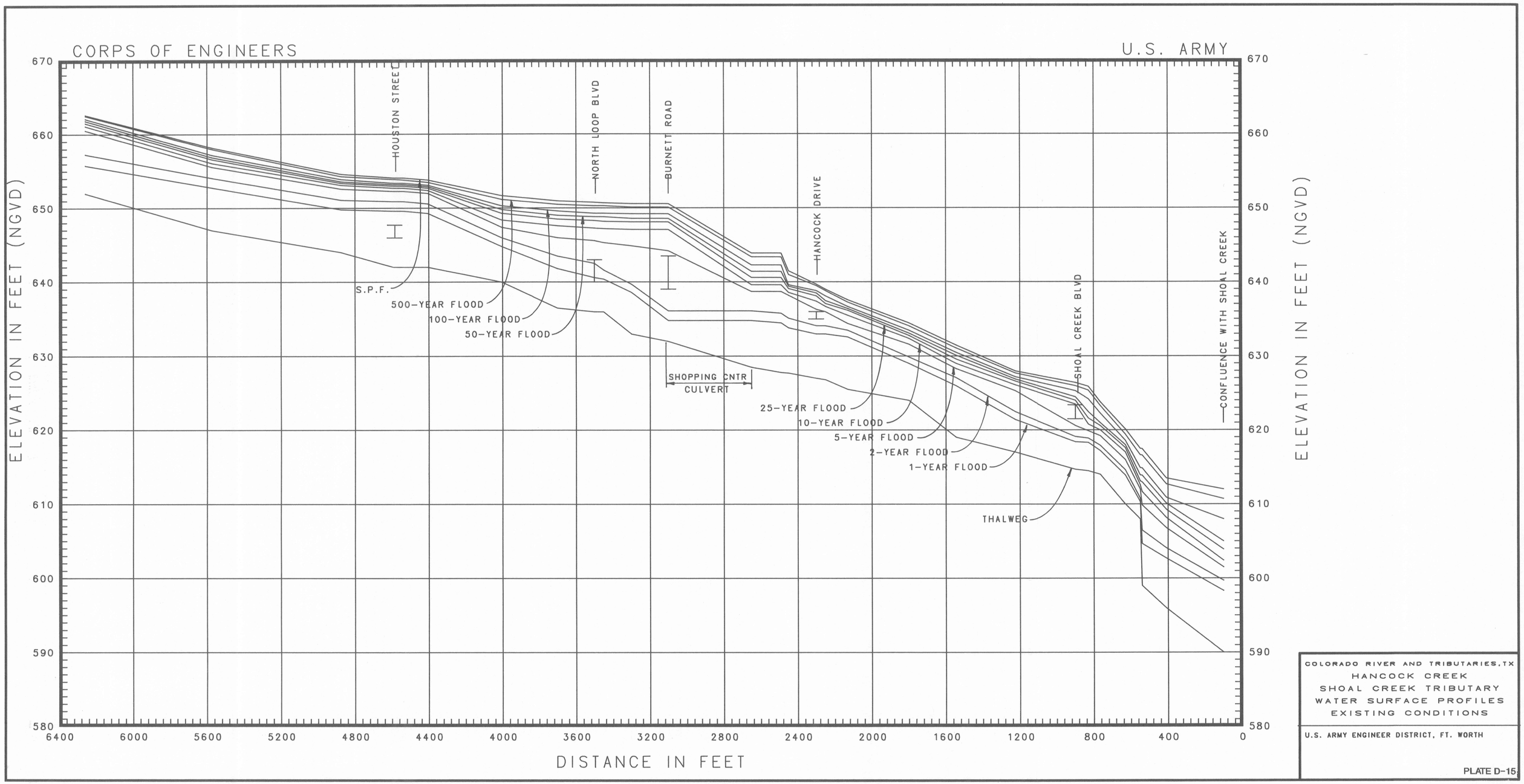
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-12


CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
740
730
720
710
700
690
680
670
660
650
ANDERSON LANE
FOSTER LANE
GREEN LAWN PARKWAY
SHOAL CREEK BOULEVARD
45500
45000
44500
44000
43500
43000
42500
42000
41500
41000
40500
40000
39500
39000
38500
38000
37500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-13

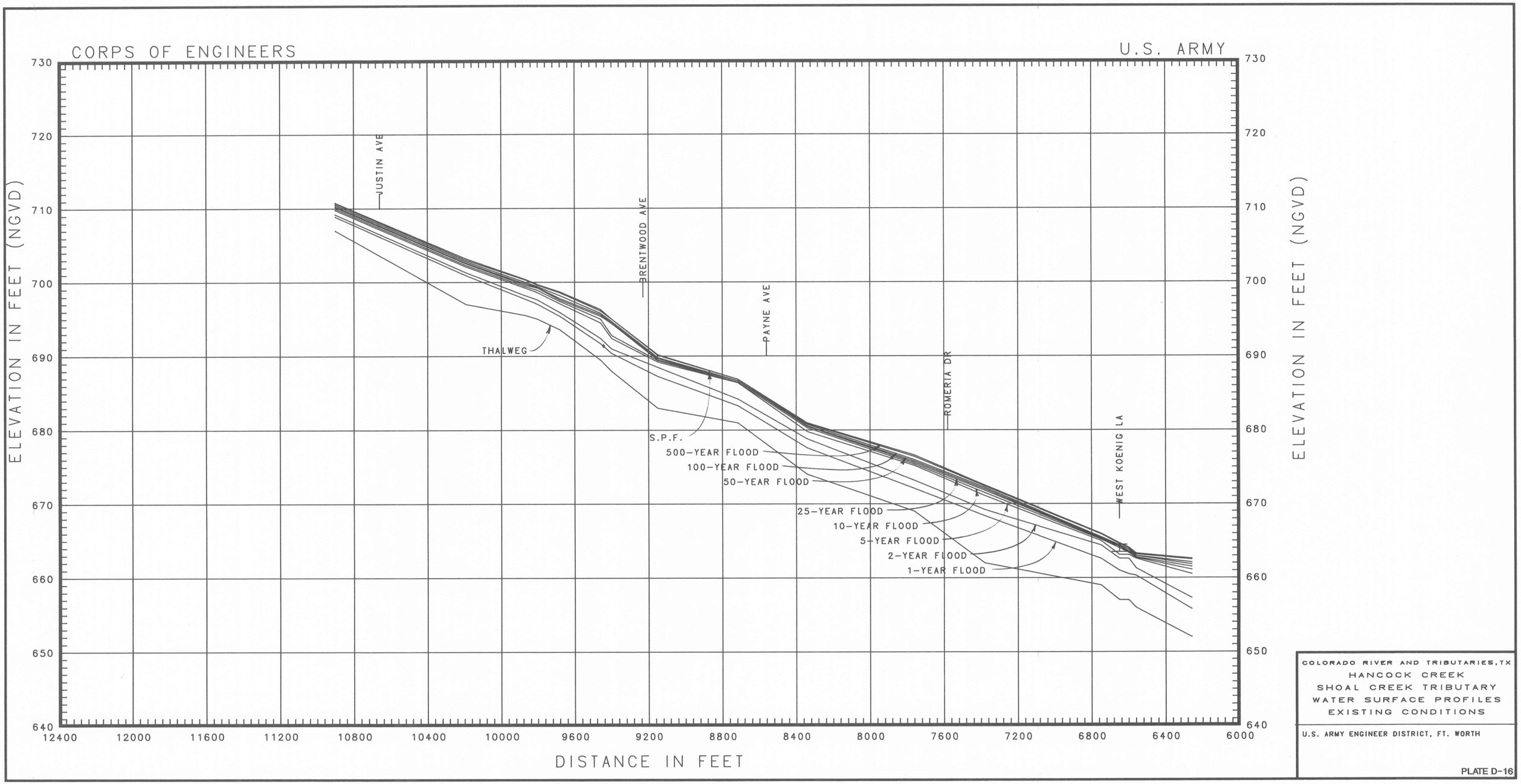

CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
780
770
760
750
740
730
720
710
700
690
MOPAC RR
U. S. 183
U. S. 183
SHOAL CREEK BOULEVARD
CROSS CREEK DRIVE
STECK AVENUE
52500
52000
51500
51000
50500
50000
49500
49000
48500
48000
47500
47000
46500
46000
45500
45000
44500
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
AUSTIN, TEXAS
SHOAL CREEK
EXISTING CONDITIONS
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-14



COLORADO RIVER AND TRIBUTARIES, TX
HANCOCK CREEK
SHOAL CREEK TRIBUTARY
WATER SURFACE PROFILES
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

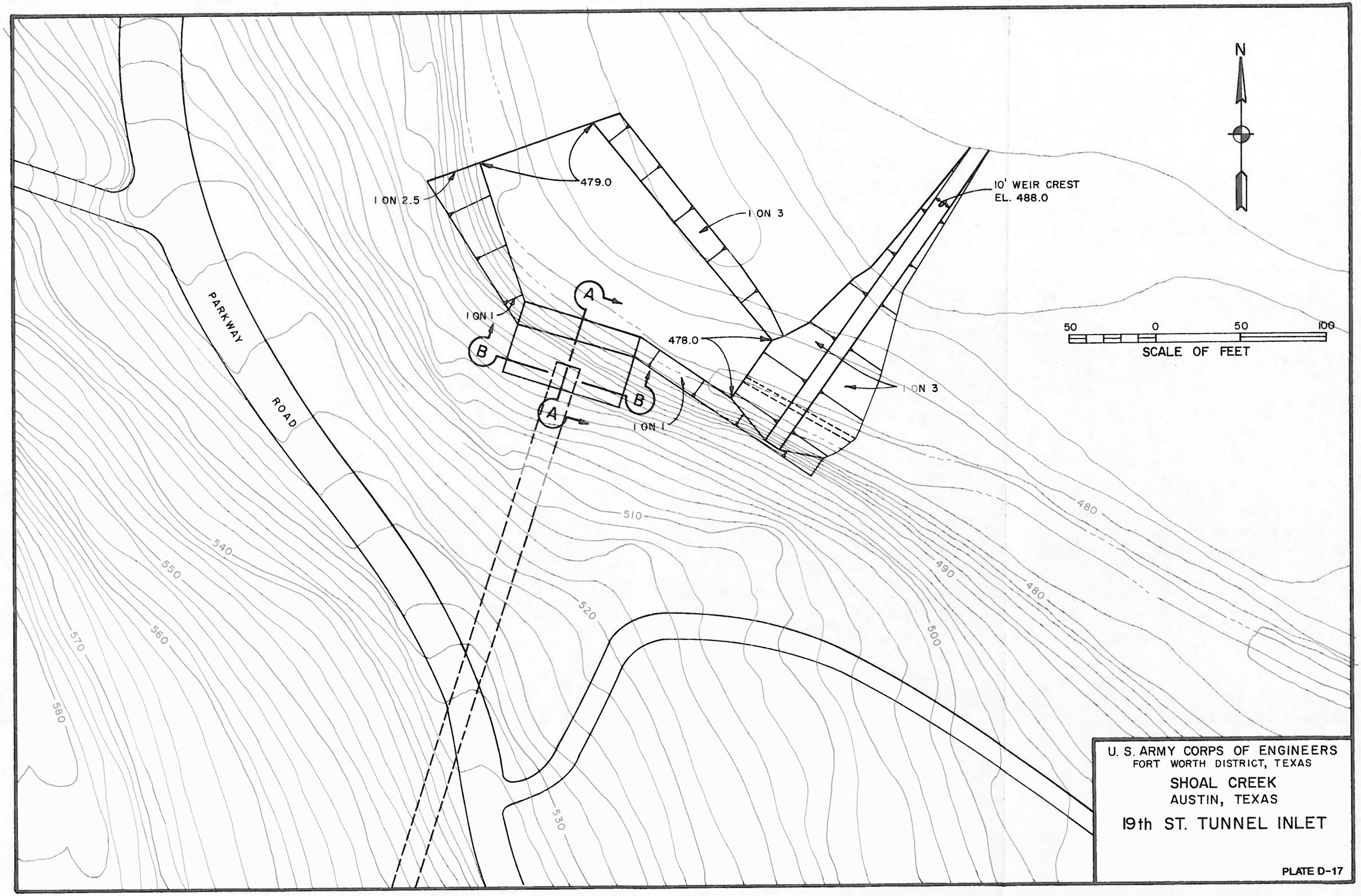
PLATE D-15



COLORADO RIVER AND TRIBUTARIES, TX
HANCOCK CREEK
SHOAL CREEK TRIBUTARY
WATER SURFACE PROFILES
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-16

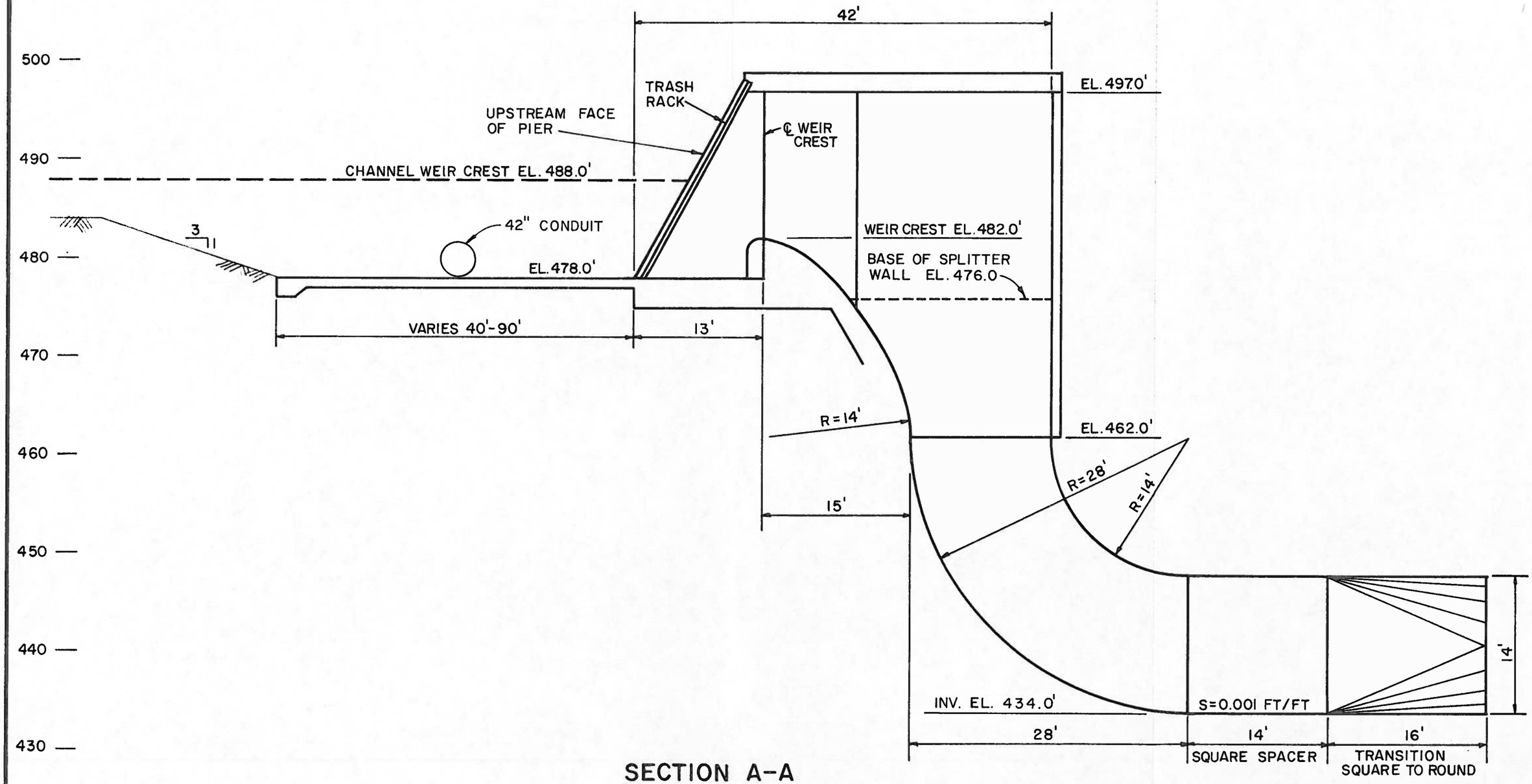


U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

19th ST. TUNNEL INLET

PLATE D-17



SECTION A-A

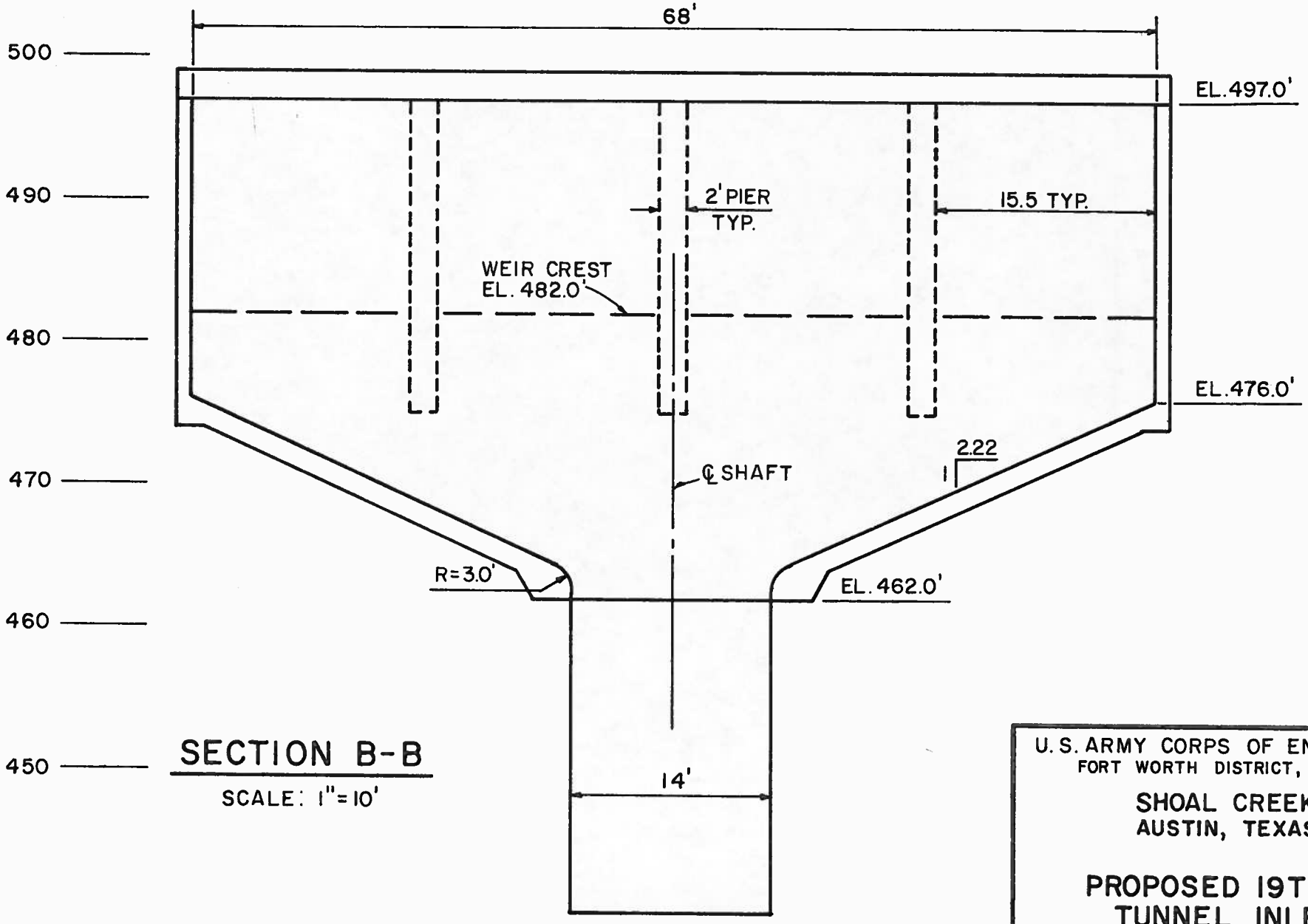
SCALE: 1"=10'

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

SHOAL CREEK
AUSTIN, TEXAS

PROPOSED 19TH ST.
TUNNEL INLET

PLATE D-18



SECTION B-B

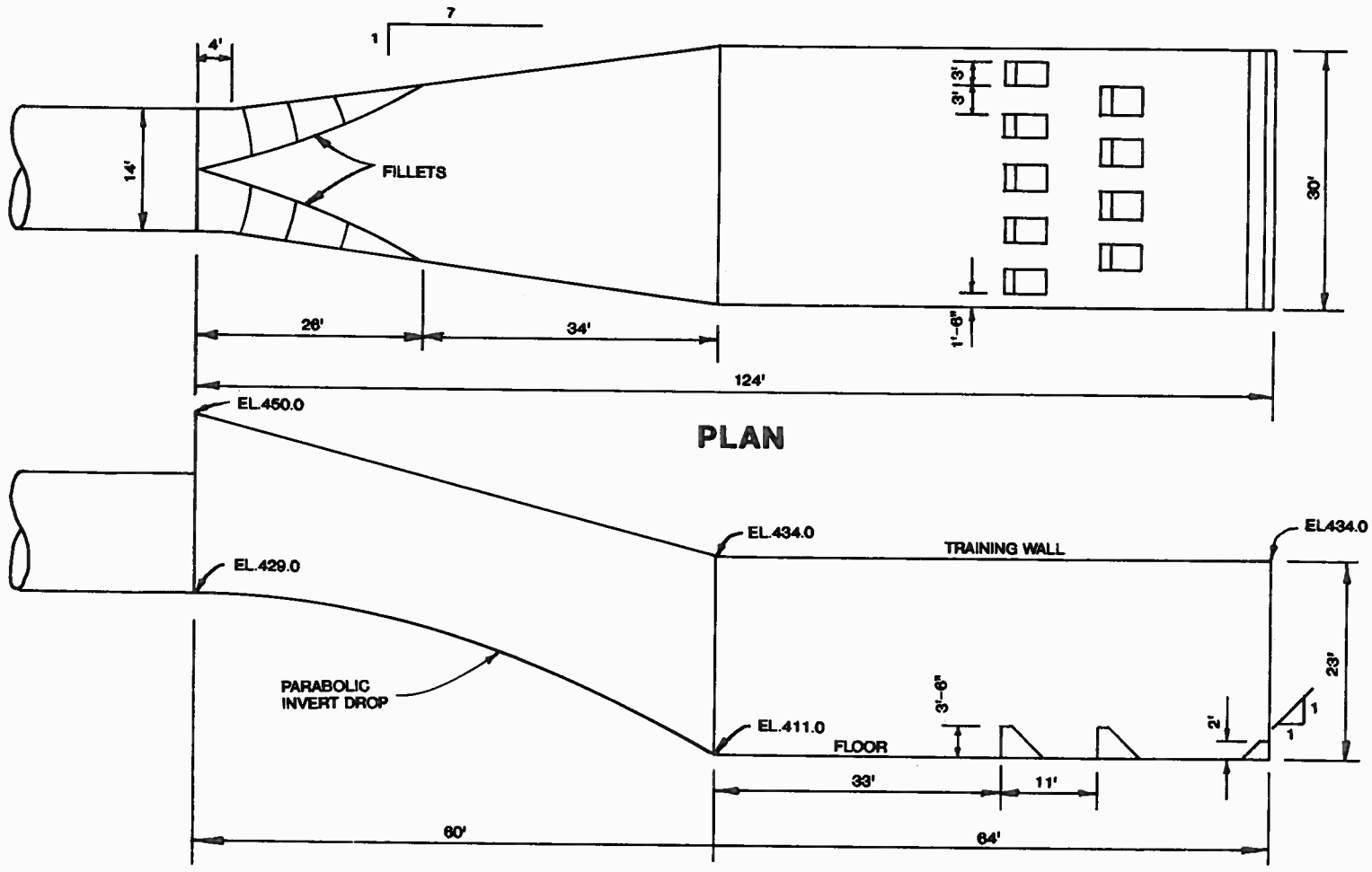
SCALE: 1" = 10'

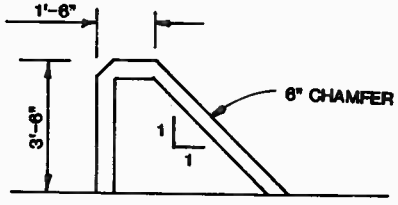
U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

PROPOSED 19TH ST.
TUNNEL INLET

PLATE D-19





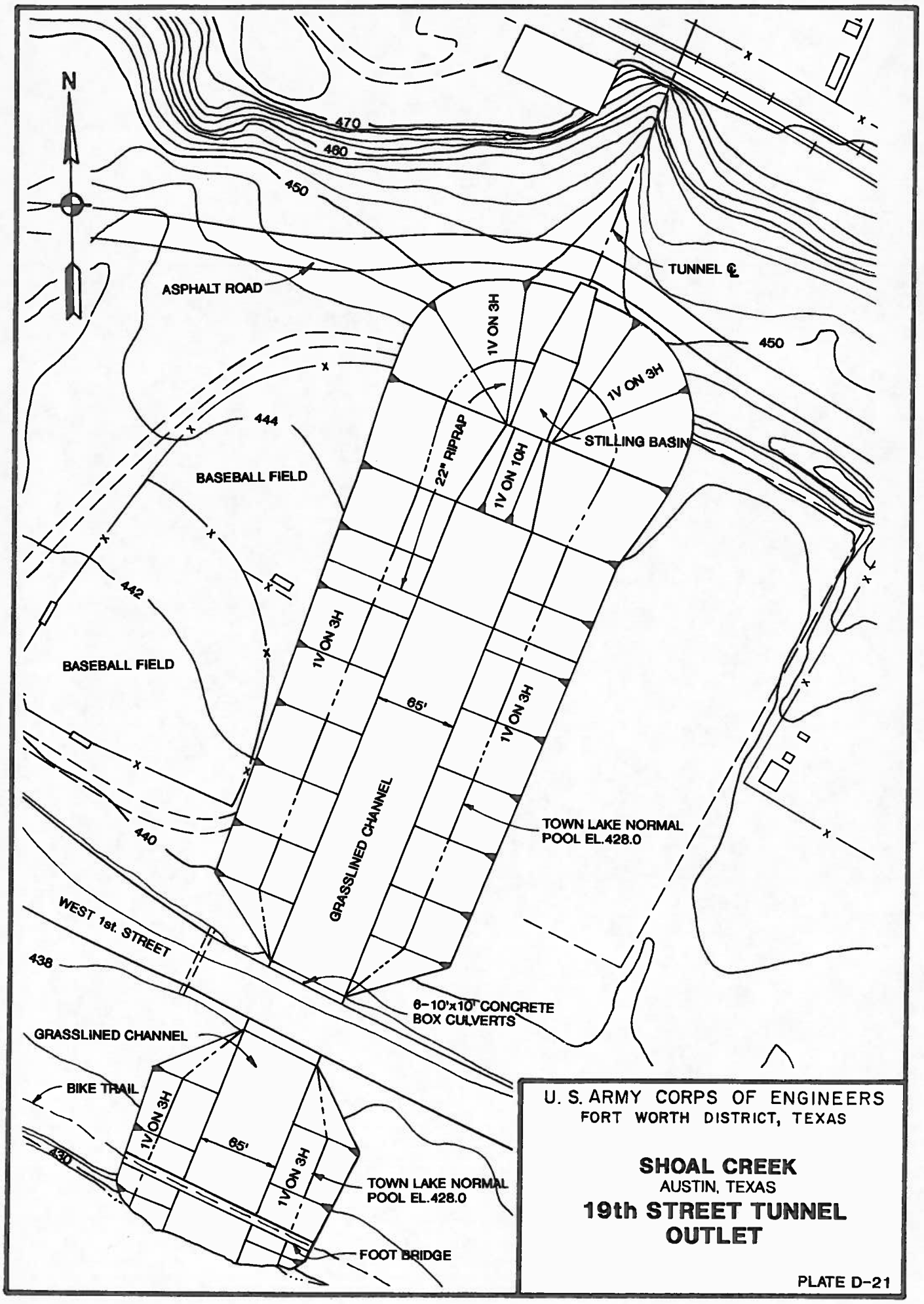
BAFFLE PIER DETAIL

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

SHOAL CREEK
AUSTIN, TEXAS

STILLING BASIN LAYOUT
19th ST. TUNNEL OUTLET

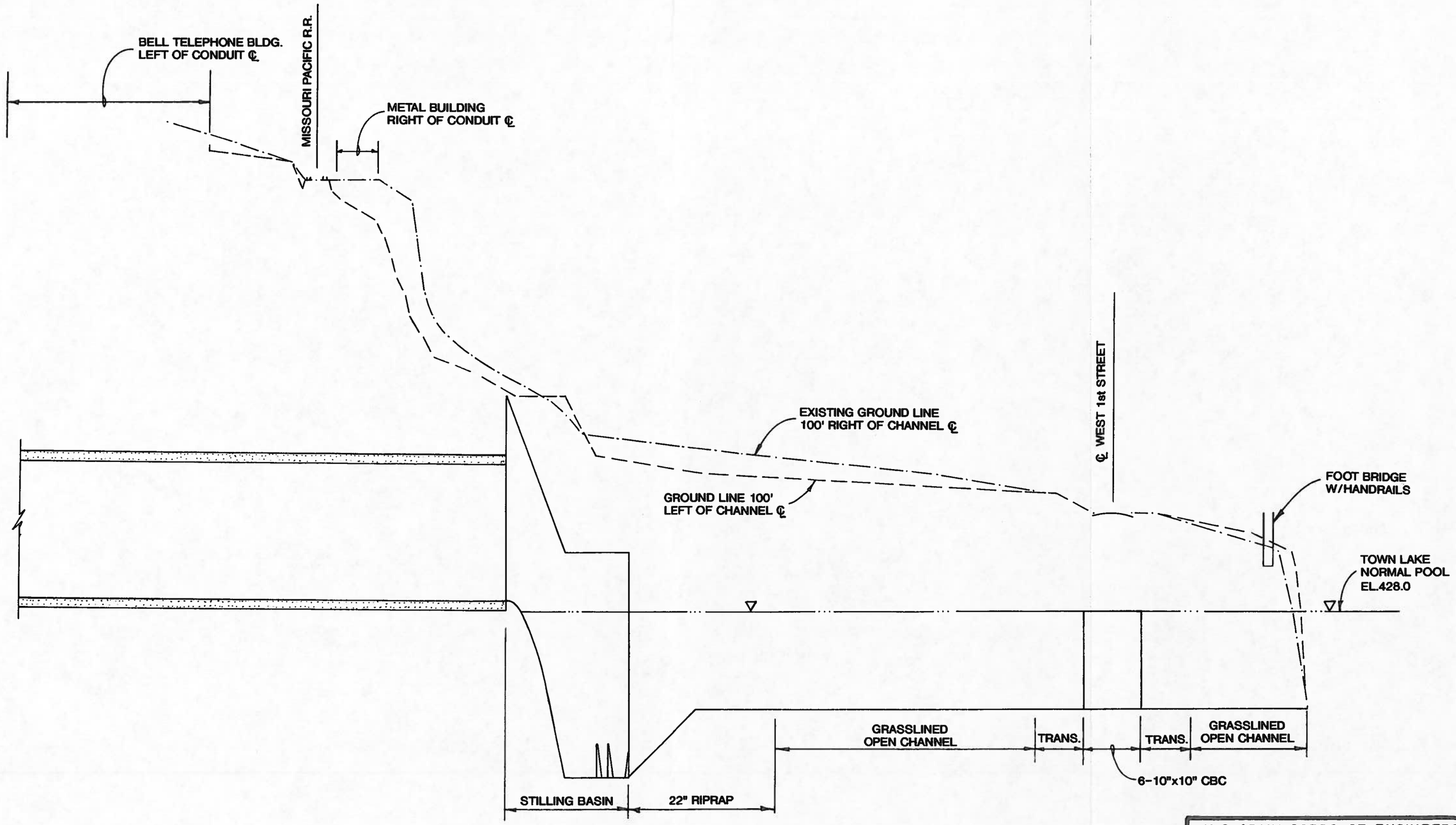
PLATE D-20



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

SHOAL CREEK
AUSTIN, TEXAS
19th STREET TUNNEL OUTLET

PLATE D-21



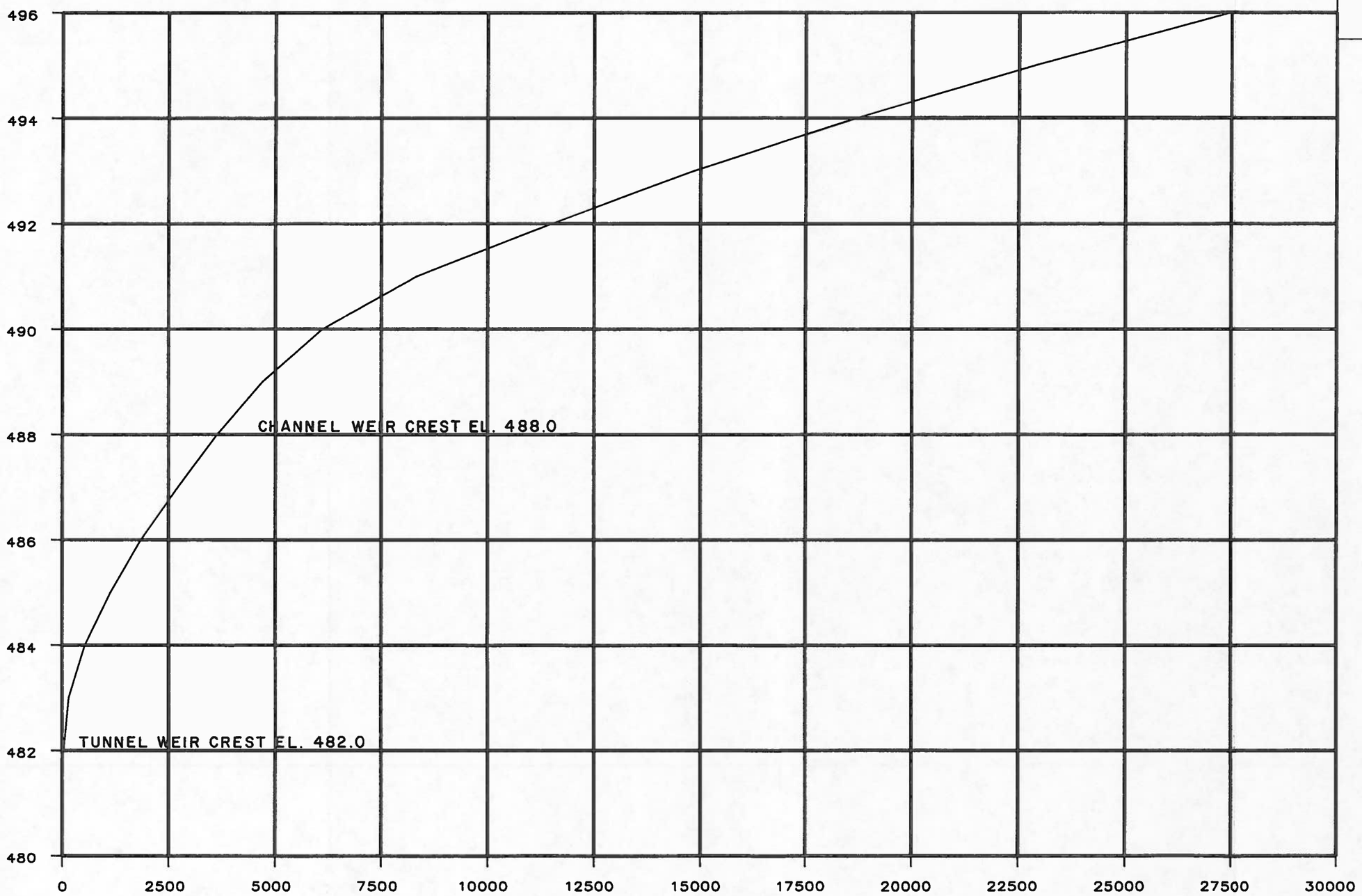
VERTICAL SCALE: 1"=10'
HORIZONTAL SCALE: 1"=100'

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

SHOAL CREEK
AUSTIN, TEXAS

OUTLET CHANNEL PROFILE
19th STREET TUNNEL

PLATE D-22



LEGEND

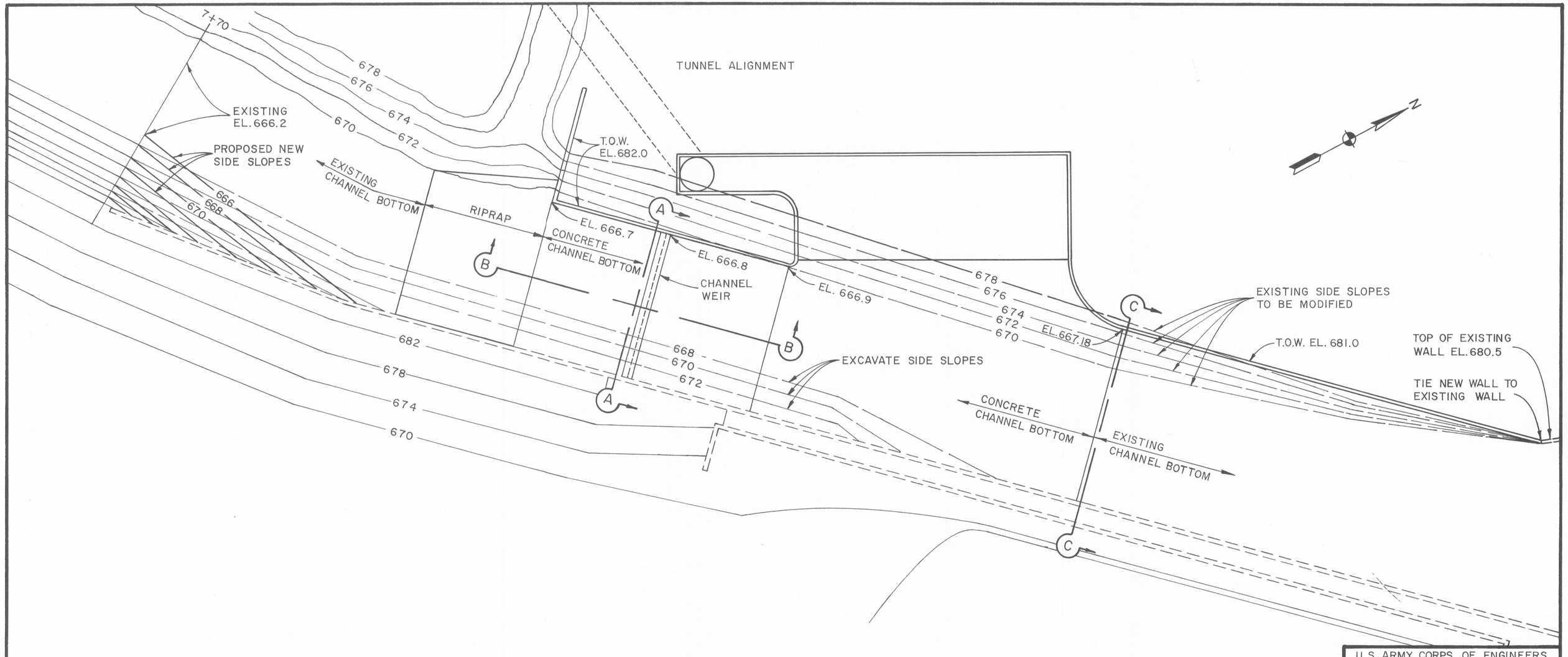
ELEVATION VERSUS DISCHARGE

5 OCT 89

COLORADO RIVER AND TRIBUTARIES, TX

SHOAL CREEK
RATING CURVE
FOR TUNNEL INTAKE
NINETEENTH STREET TUNNEL

U.S. ARMY ENGINEER DISTRICT, FT. WORTH



PLAN

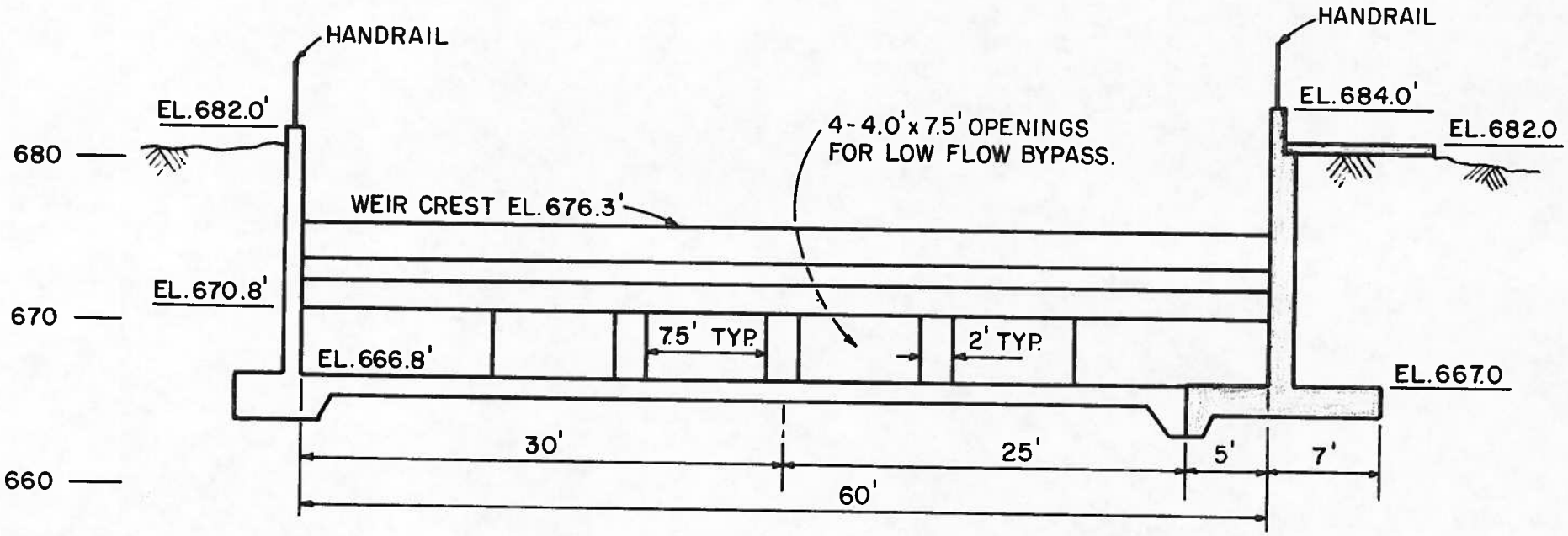
SCALE: 1"=30'

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

SHOAL CREEK
AUSTIN, TEXAS

NW PARK TUNNEL
INLET STRUCTURE
SITE PLAN

PLATE D-24



NOTE: SHADED IS EXISTING DETENTION WEIR STRUCTURE.

SECTION A-A

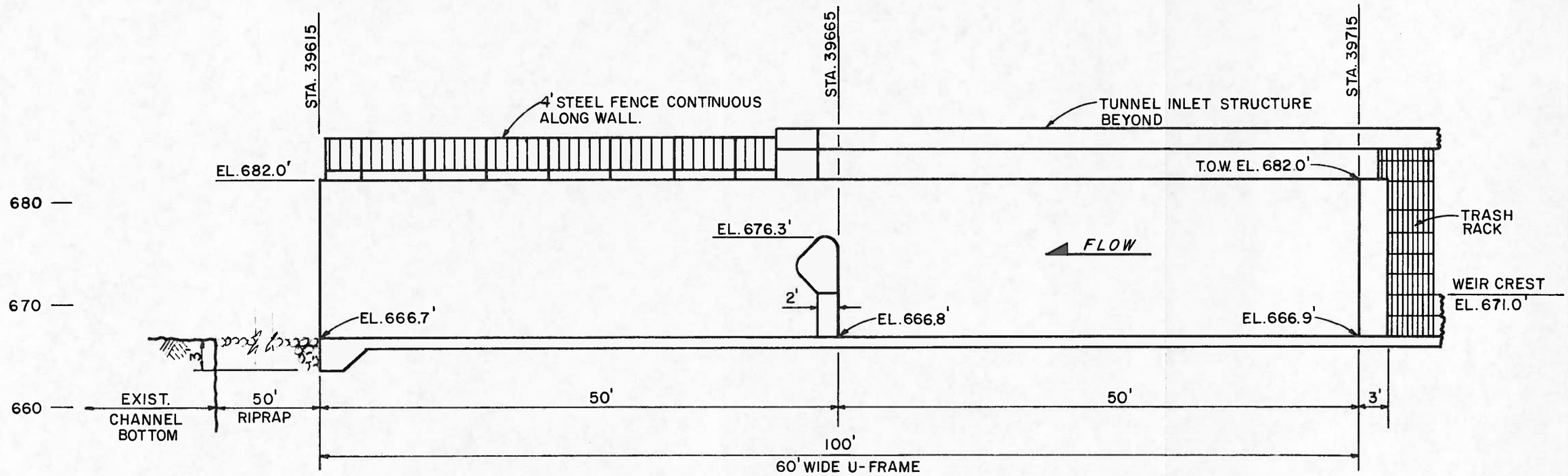
SCALE: 1"=10'

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

SHOAL CREEK
AUSTIN, TEXAS

NW PARK TUNNEL
INLET STRUCTURE

60' U-CHANNEL X-SECTION AT WEIR



SECTION B-B

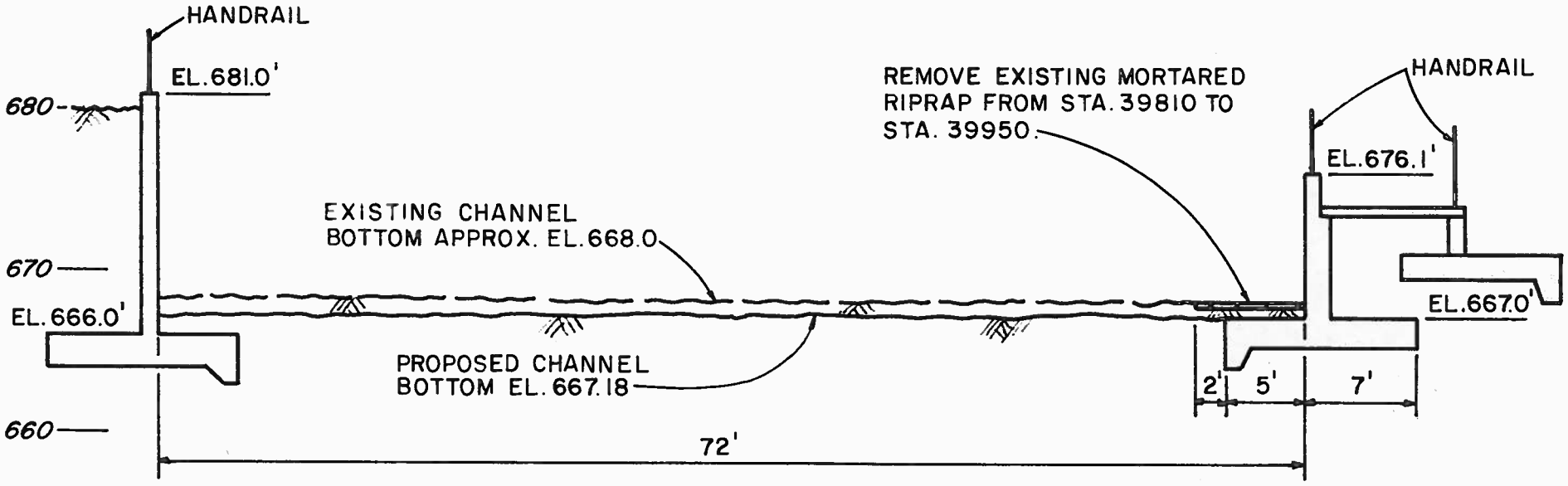
SCALE: 1" = 10'

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

SHOAL CREEK
AUSTIN, TEXAS

60' U-CHANNEL
LONGITUDINAL SECTION

PLATE D-26



NOTE: SHADED IS EXISTING DETENTION WEIR STRUCTURE

SECTION C-C

STATION 69855

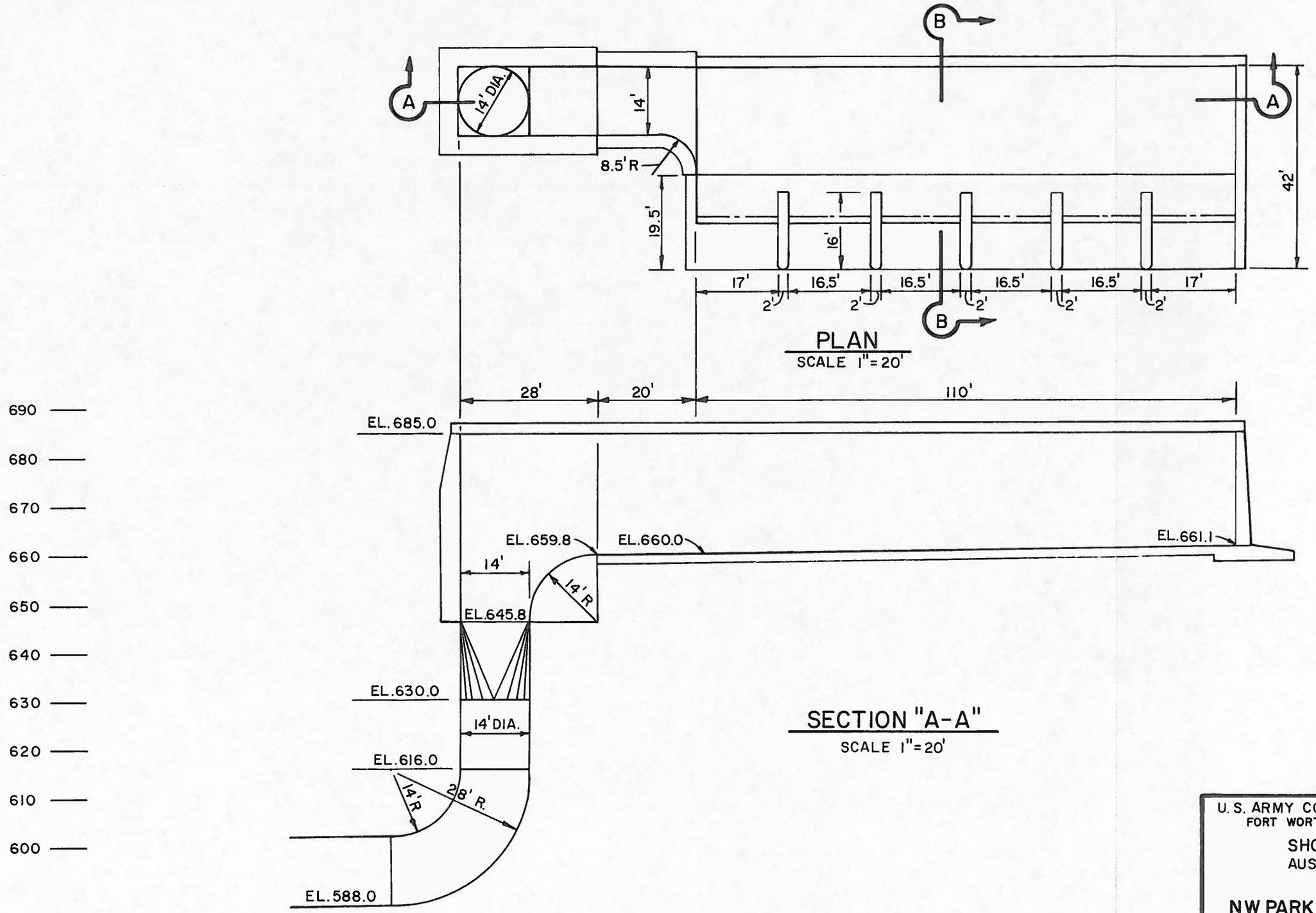
SCALE: 1" = 10'

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

SHOAL CREEK
AUSTIN, TEXAS

NW PARK TUNNEL INLET STRUCTURE

72' U-CHANNEL X-SECTION

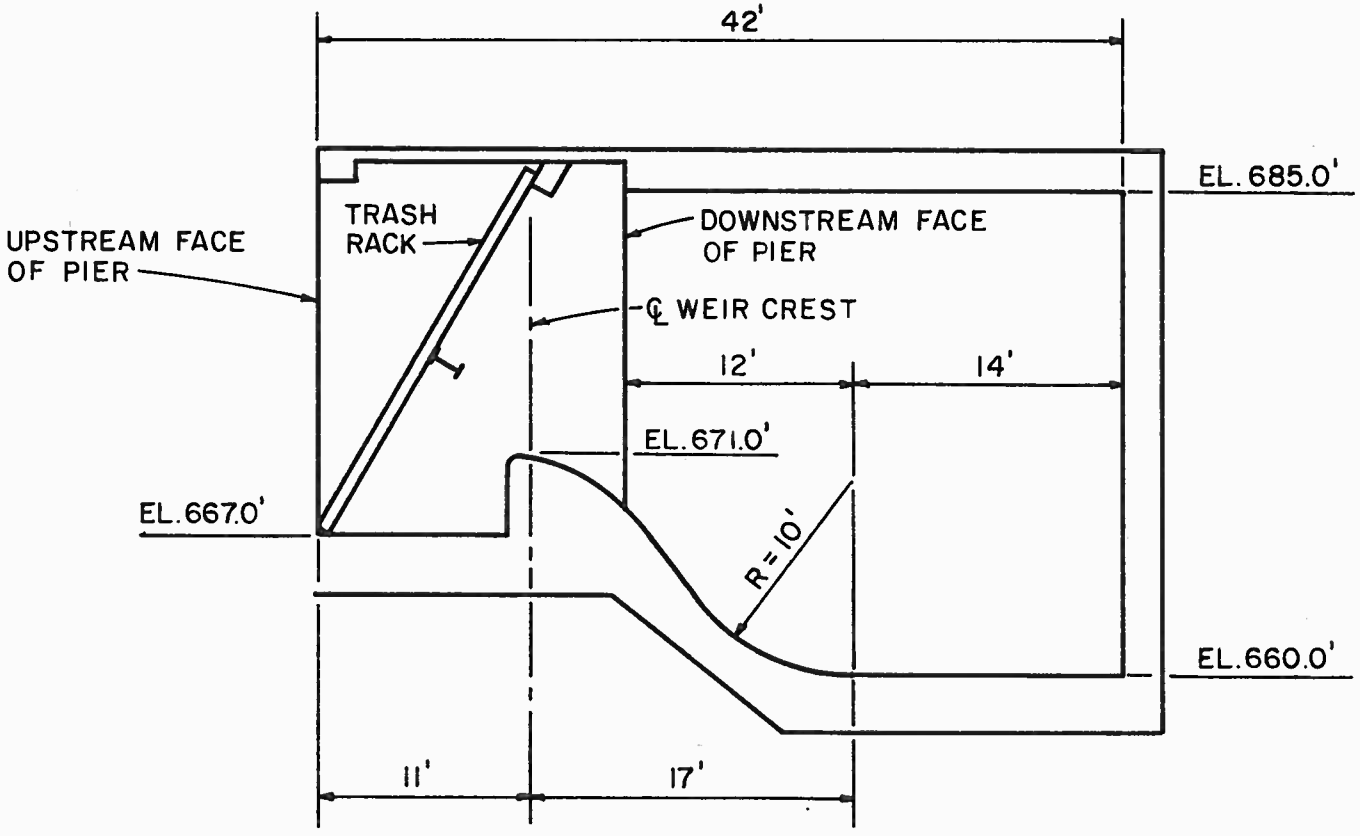


U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

NW PARK TUNNEL INLET

PLATE D-28



SECTION B—B

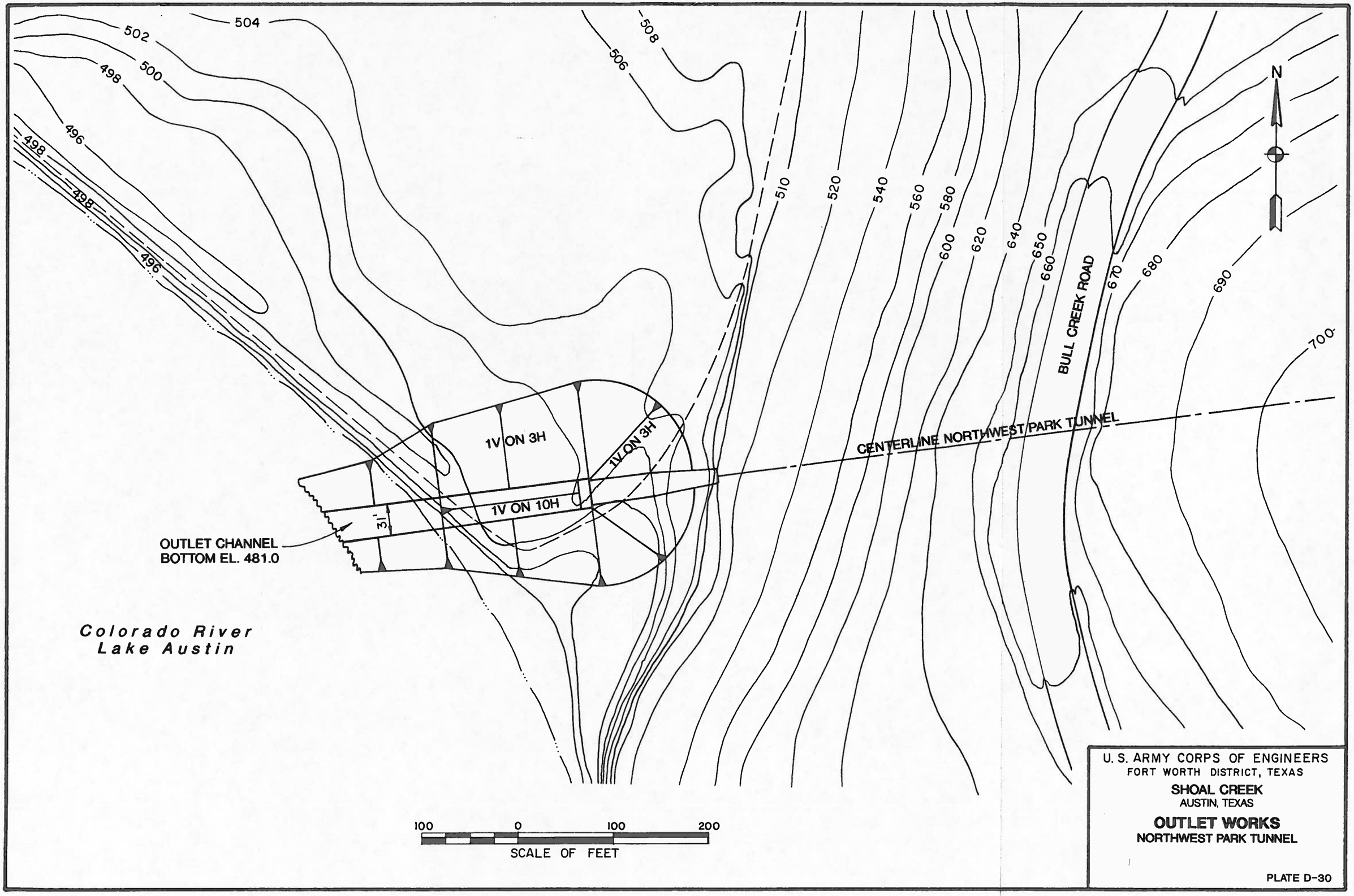
SCALE: 1" = 10'

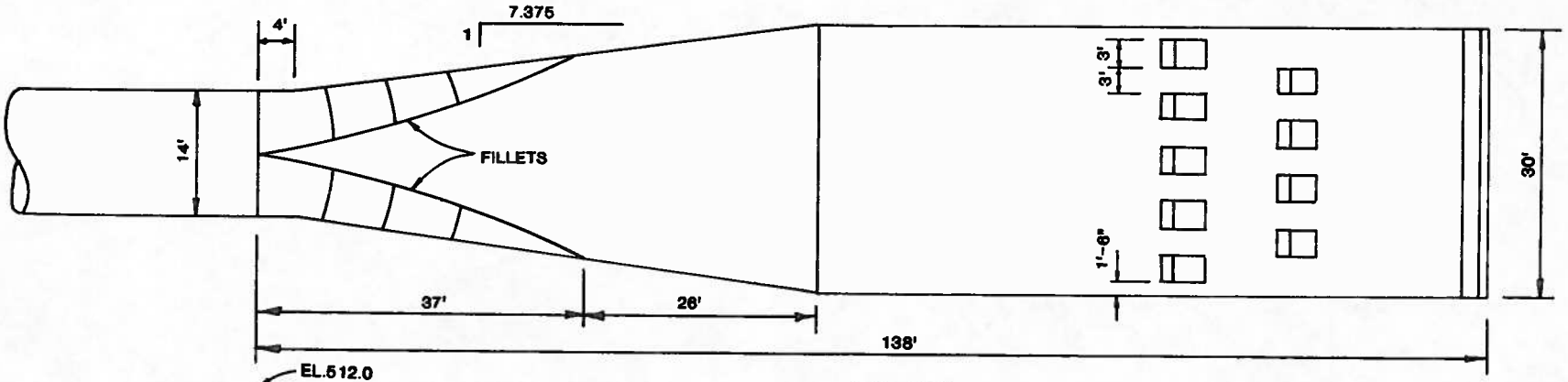
U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

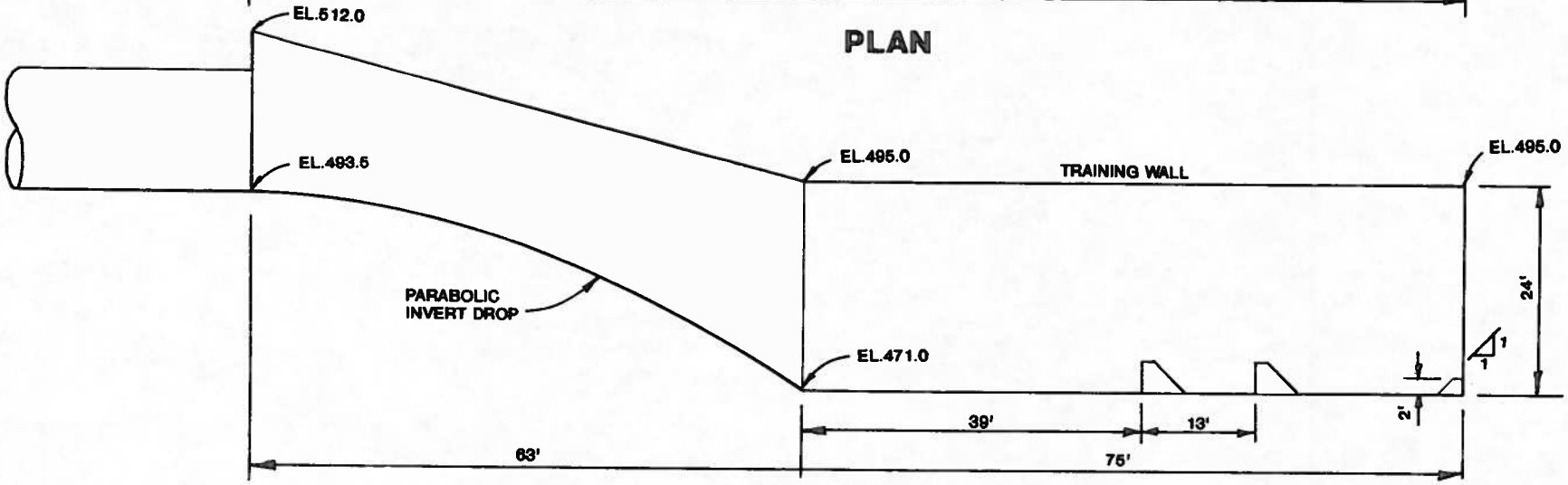
NW PARK TUNNEL INLET

PLATE D-29

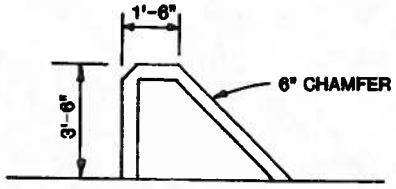

504
502
500
498
496
498
498
496
508
506
510
520
540
560
580
600
620
640
650
660
670
680
690
700
N
BULL CREEK ROAD
CENTERLINE NORTHWEST PARK TUNNEL
1V ON 3H
1V ON 3H
1V ON 10H
31'
OUTLET CHANNEL
BOTTOM EL. 481.0
Colorado River
Lake Austin
100
0
100
200
SCALE OF FEET
U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
OUTLET WORKS
NORTHWEST PARK TUNNEL
PLATE D-30



PLAN



SECTION



BAFFLE PIER DETAIL

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

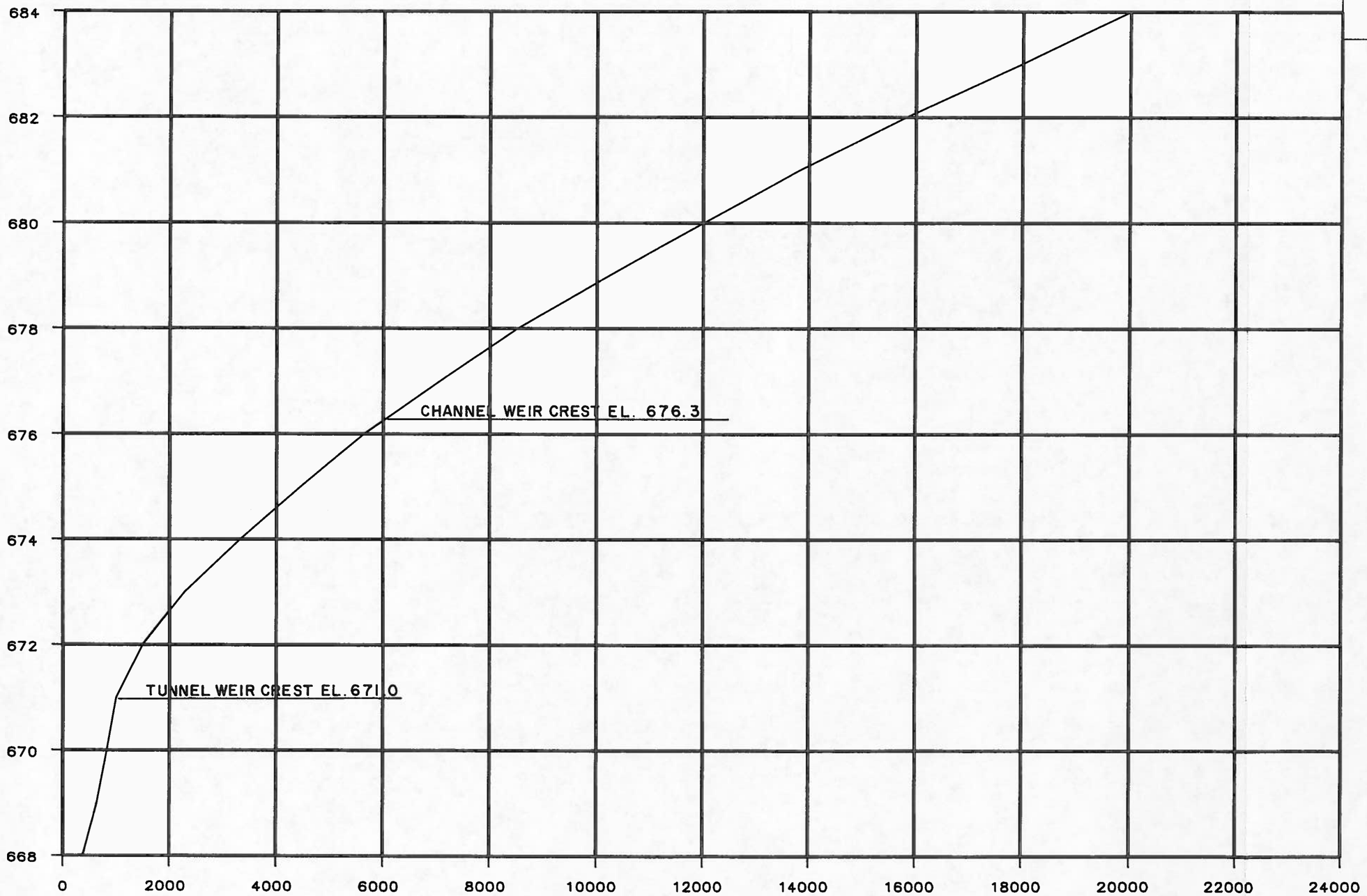
SHOAL CREEK

AUSTIN, TEXAS

STILLING BASIN LAYOUT

N.W. PARK TUNNEL OUTLET

PLATE D-31



LEGEND

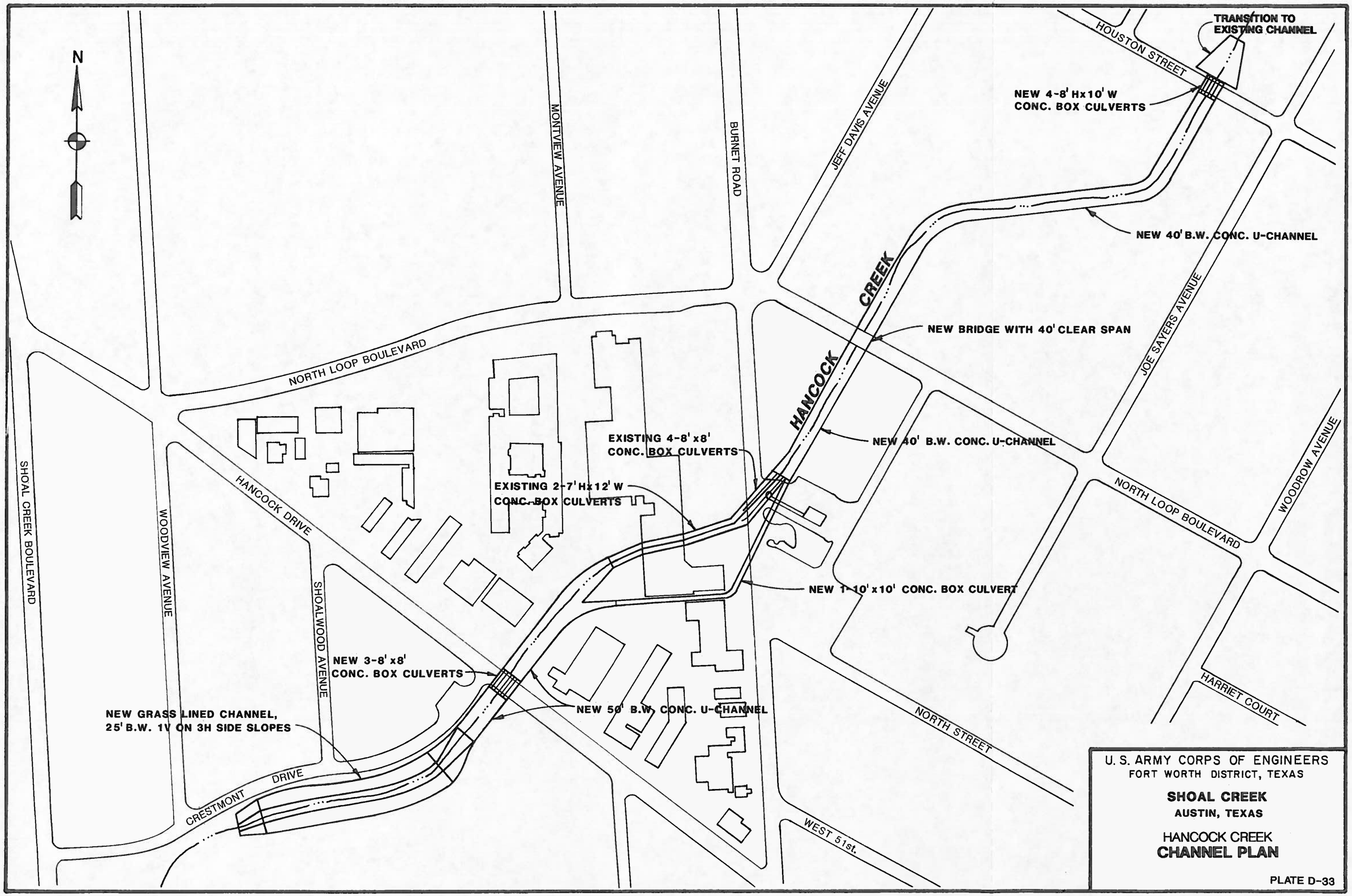
ELEVATION VERSUS DISCHARGE

5 OCT 89

COLORADO RIVER AND TRIBUTARIES, TX

SHOAL CREEK
RATING CURVE
FOR TUNNEL INTAKE
NORTHWEST PARK TUNNEL

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

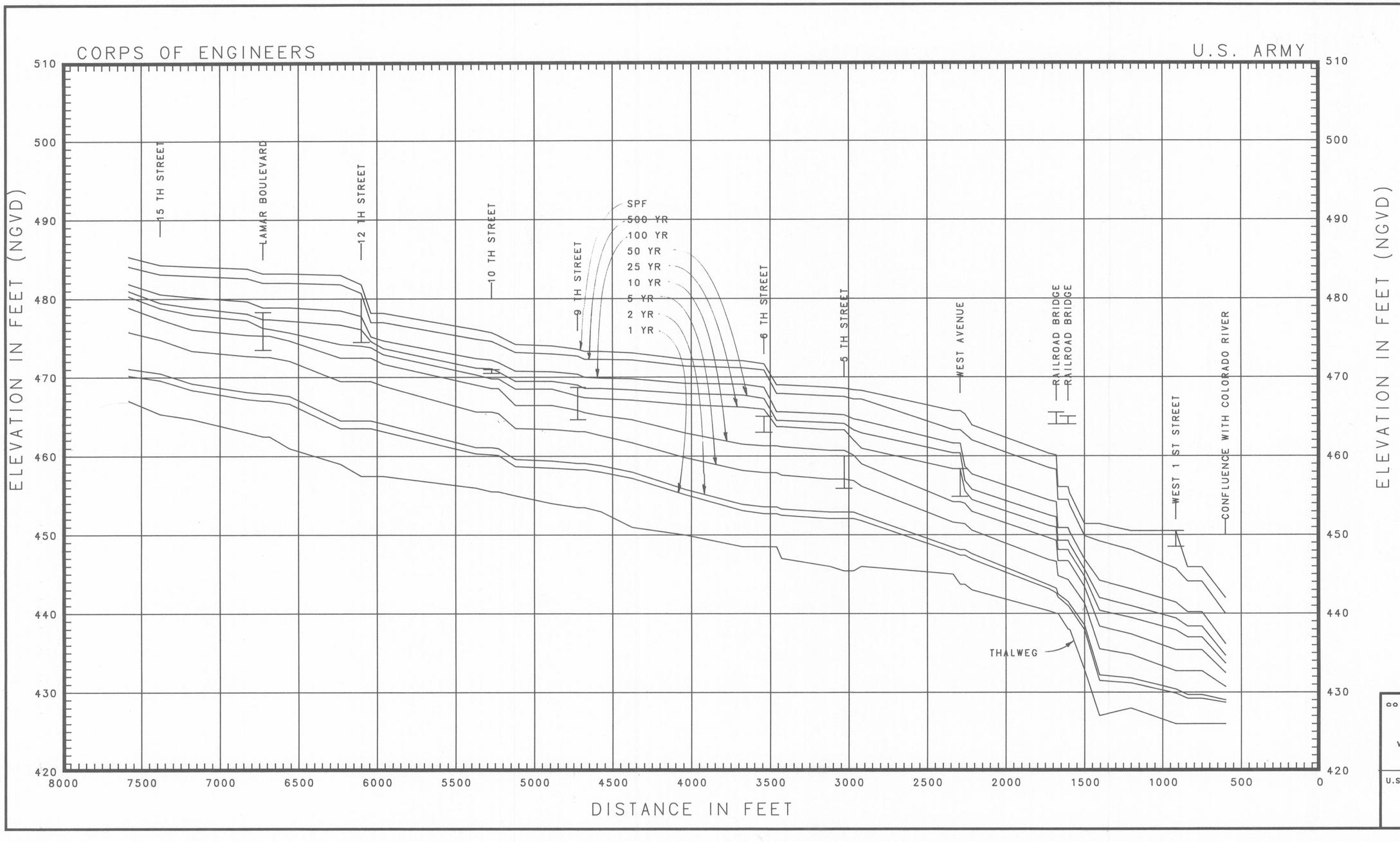


U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

HANCOCK CREEK
CHANNEL PLAN

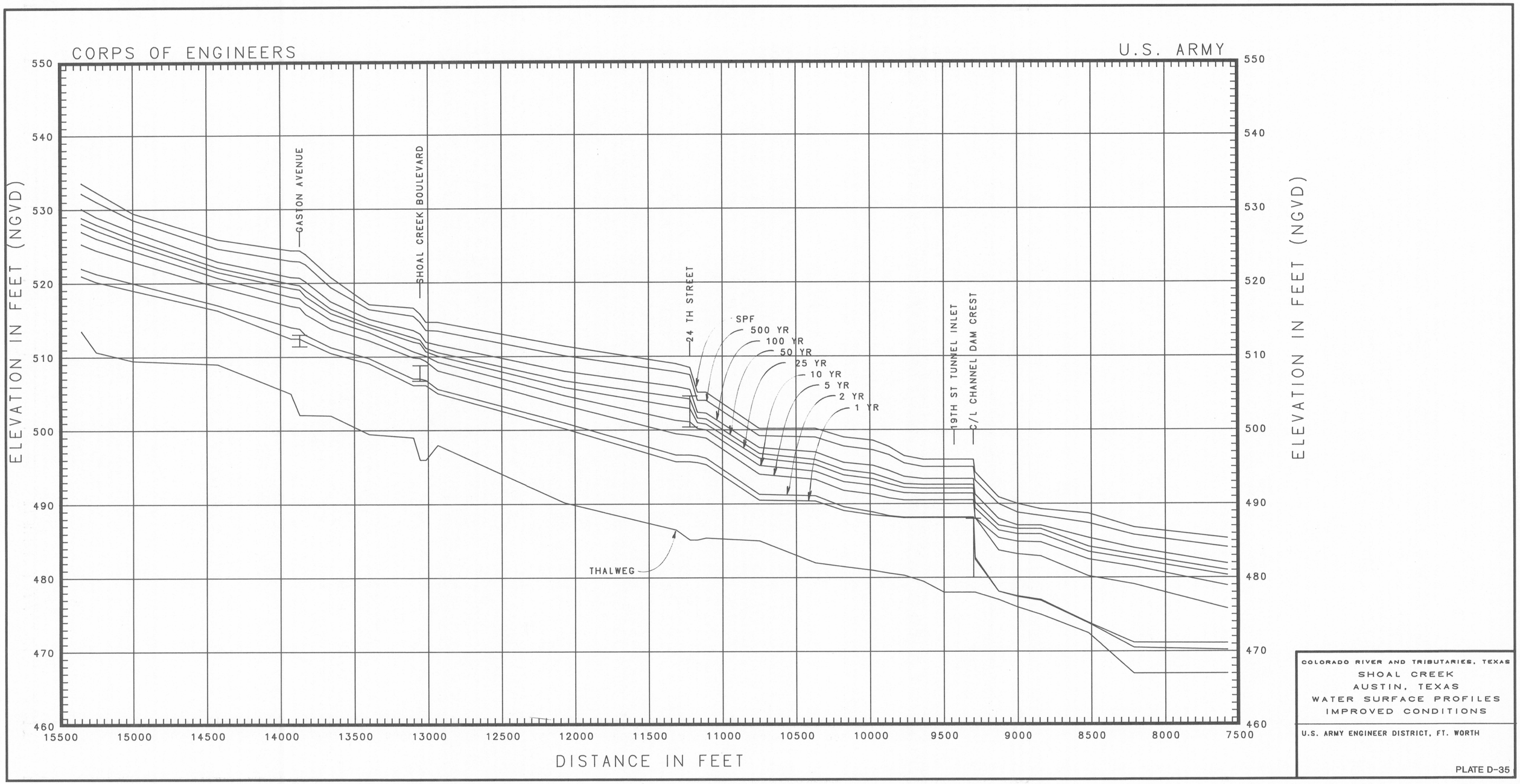
PLATE D-33



COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

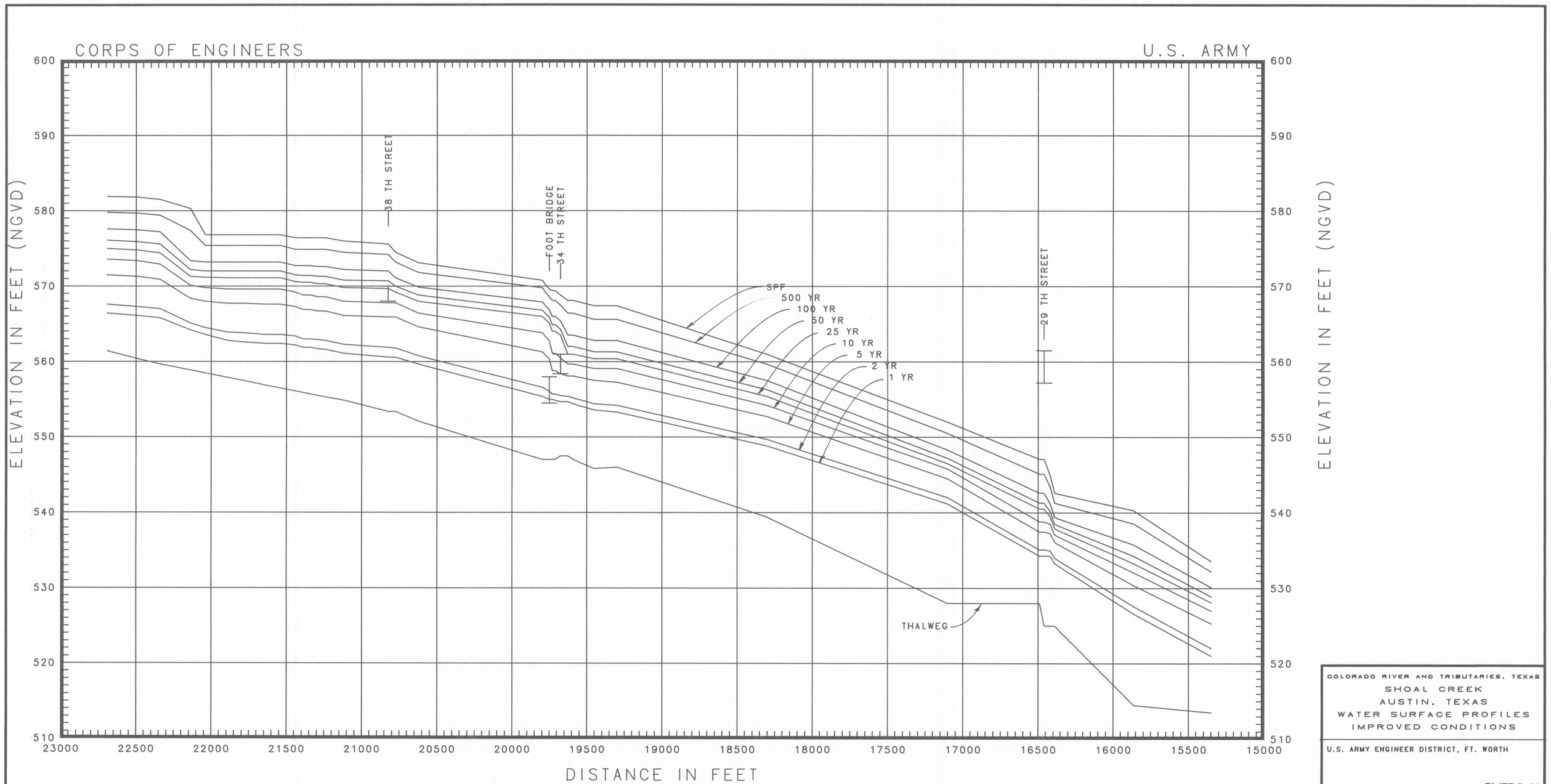
PLATE D-34



COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

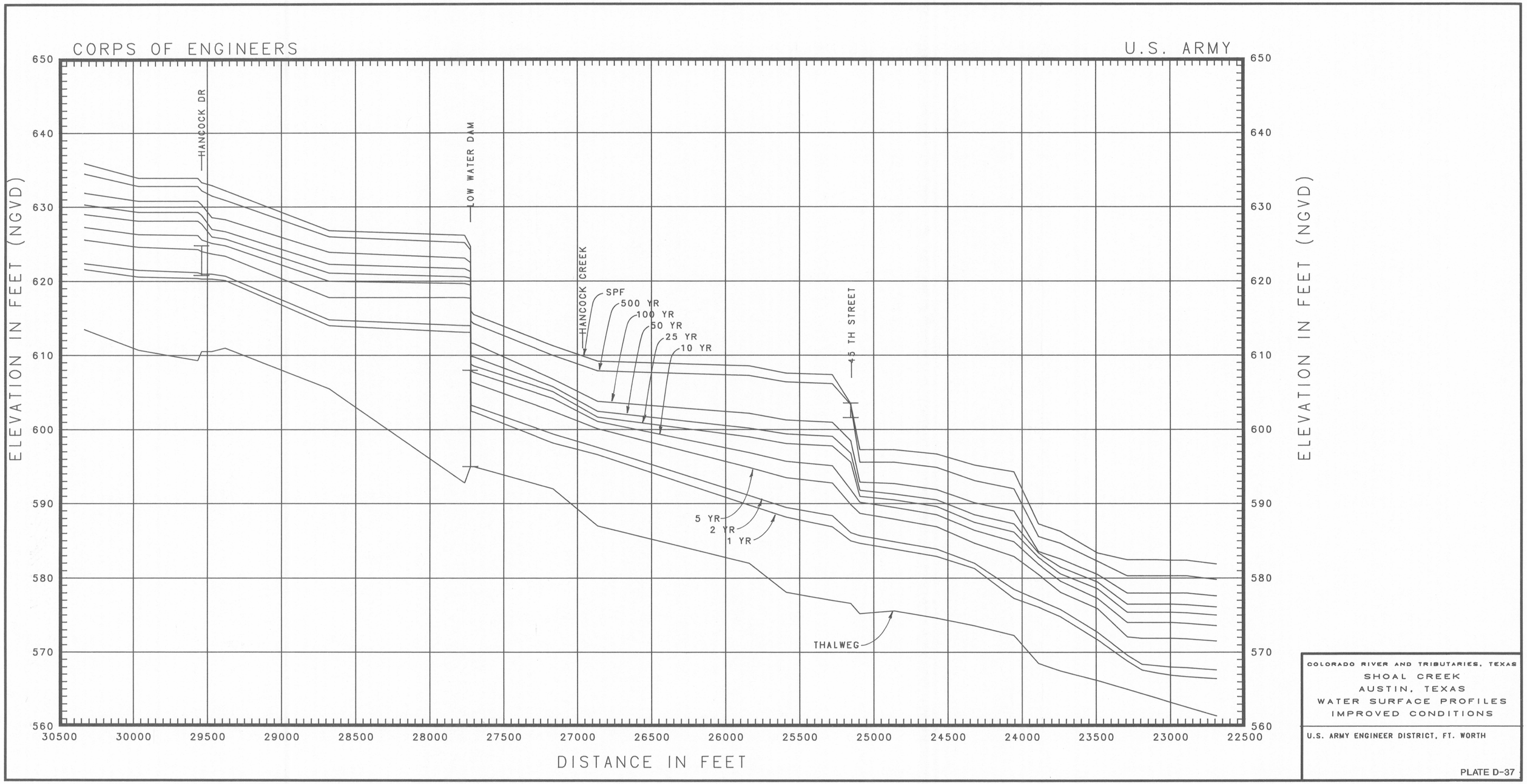
PLATE D-35



COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

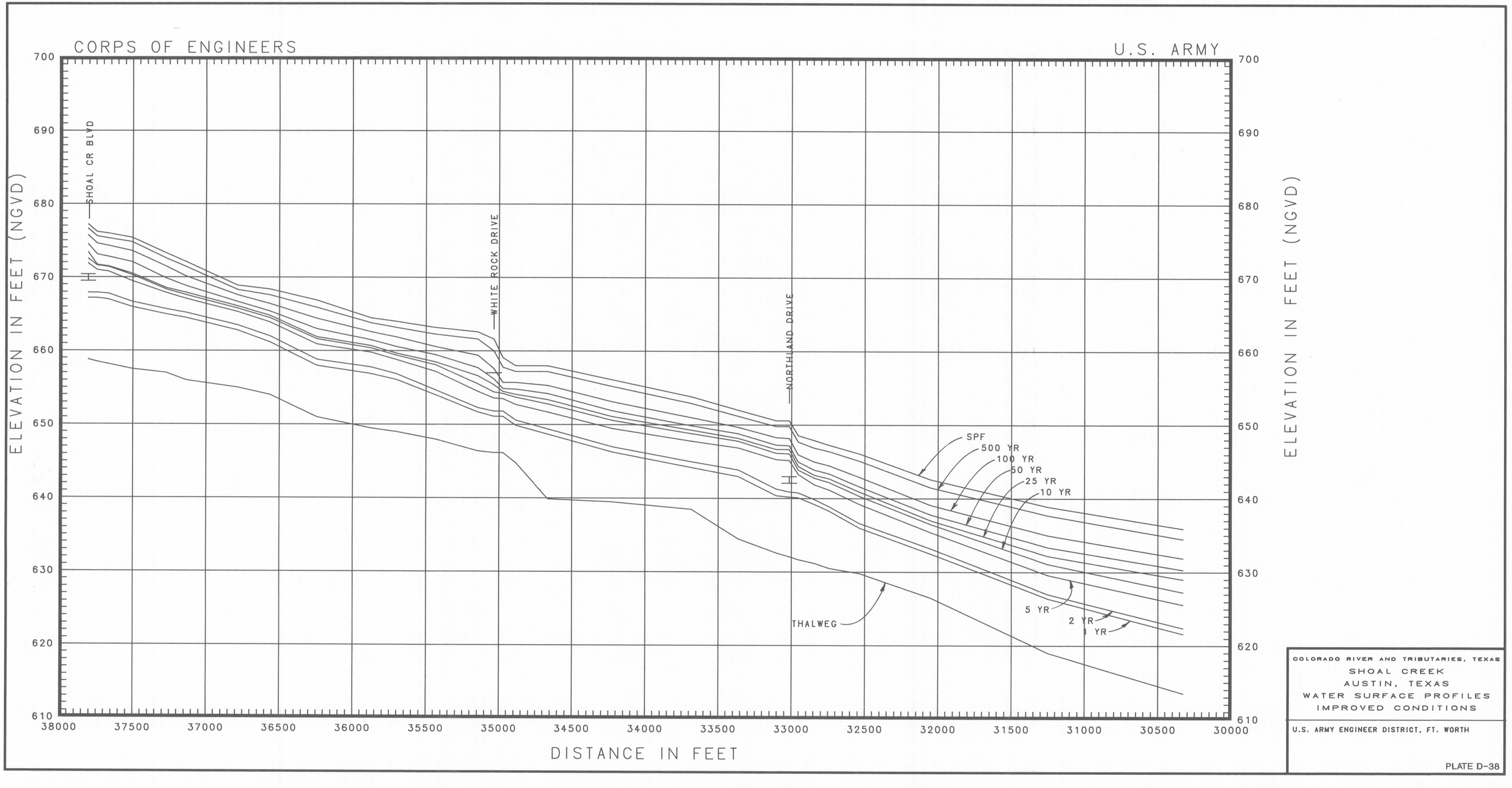
PLATE D-36

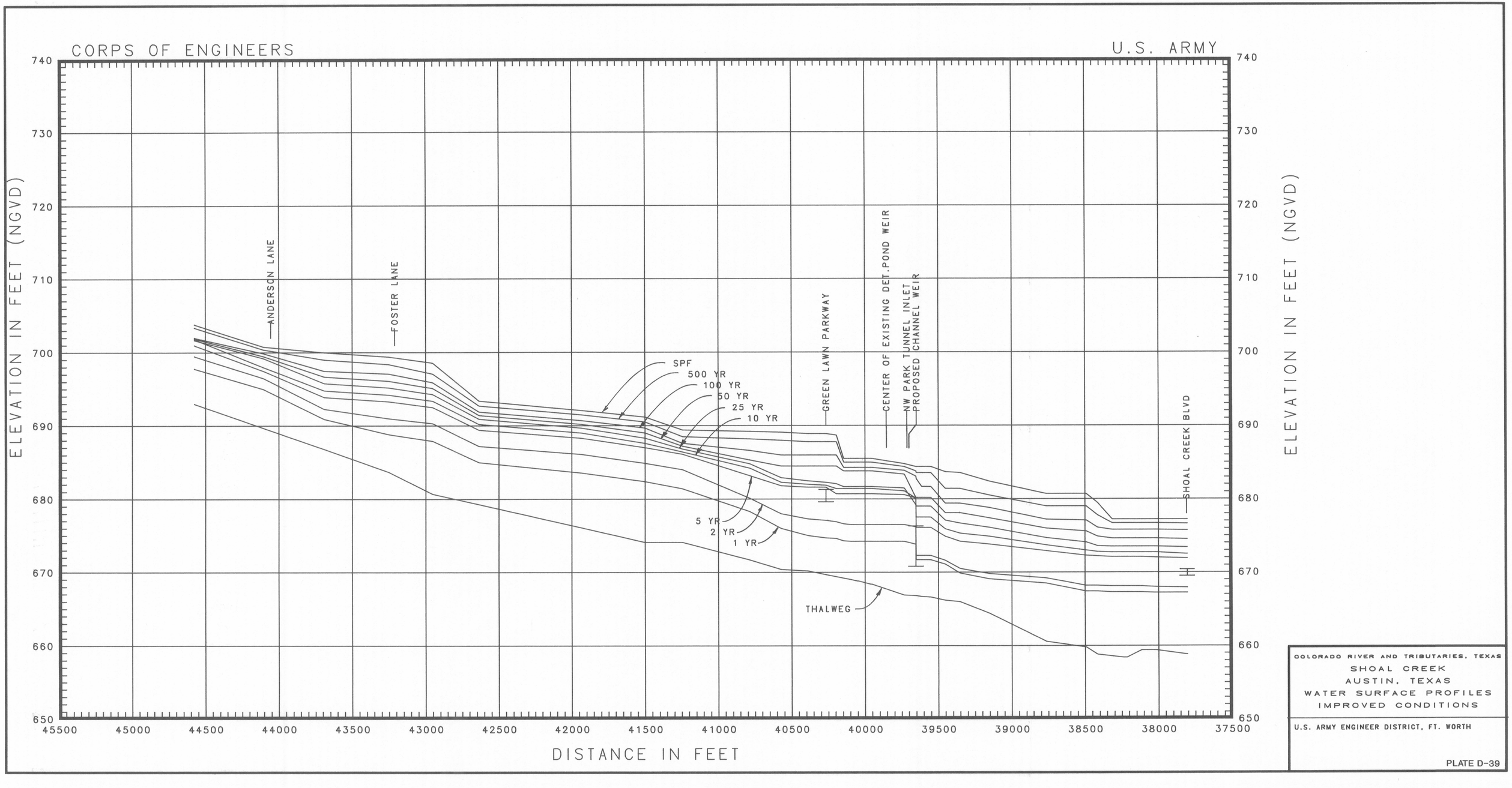


COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-37


CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
700
690
680
670
660
650
640
630
620
610
SHOAL CR BLVD
WHITE ROCK DRIVE
NORTHLAND DRIVE
SPF
500 YR
100 YR
50 YR
25 YR
10 YR
5 YR
2 YR
1 YR
THALWEG
38000
37500
37000
36500
36000
35500
35000
34500
34000
33500
33000
32500
32000
31500
31000
30500
30000
DISTANCE IN FEET
COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS
U.S. ARMY ENGINEER DISTRICT, FT. WORTH
PLATE D-38

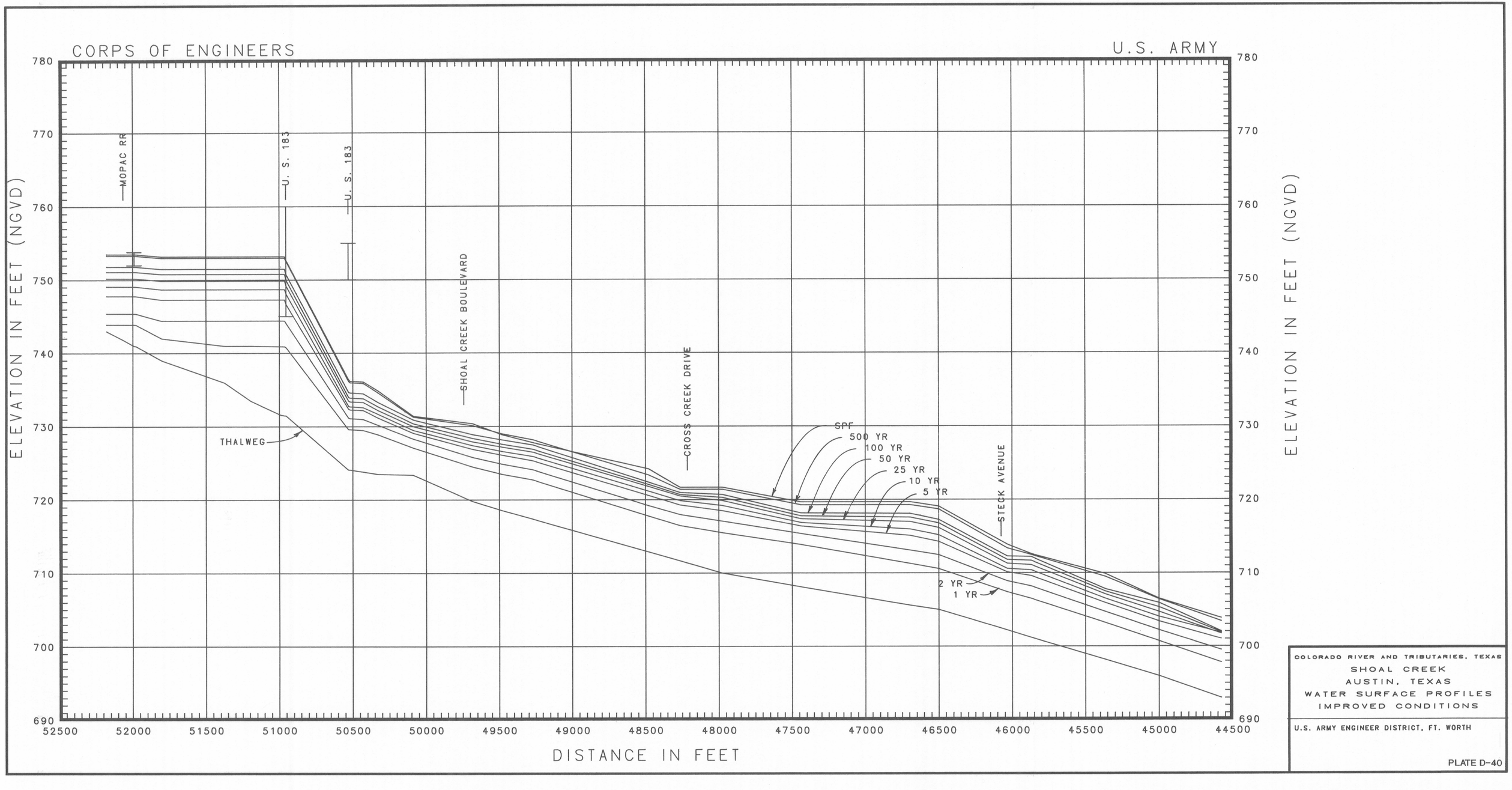


COLORADO RIVER AND TRIBUTARIES, TEXAS

SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

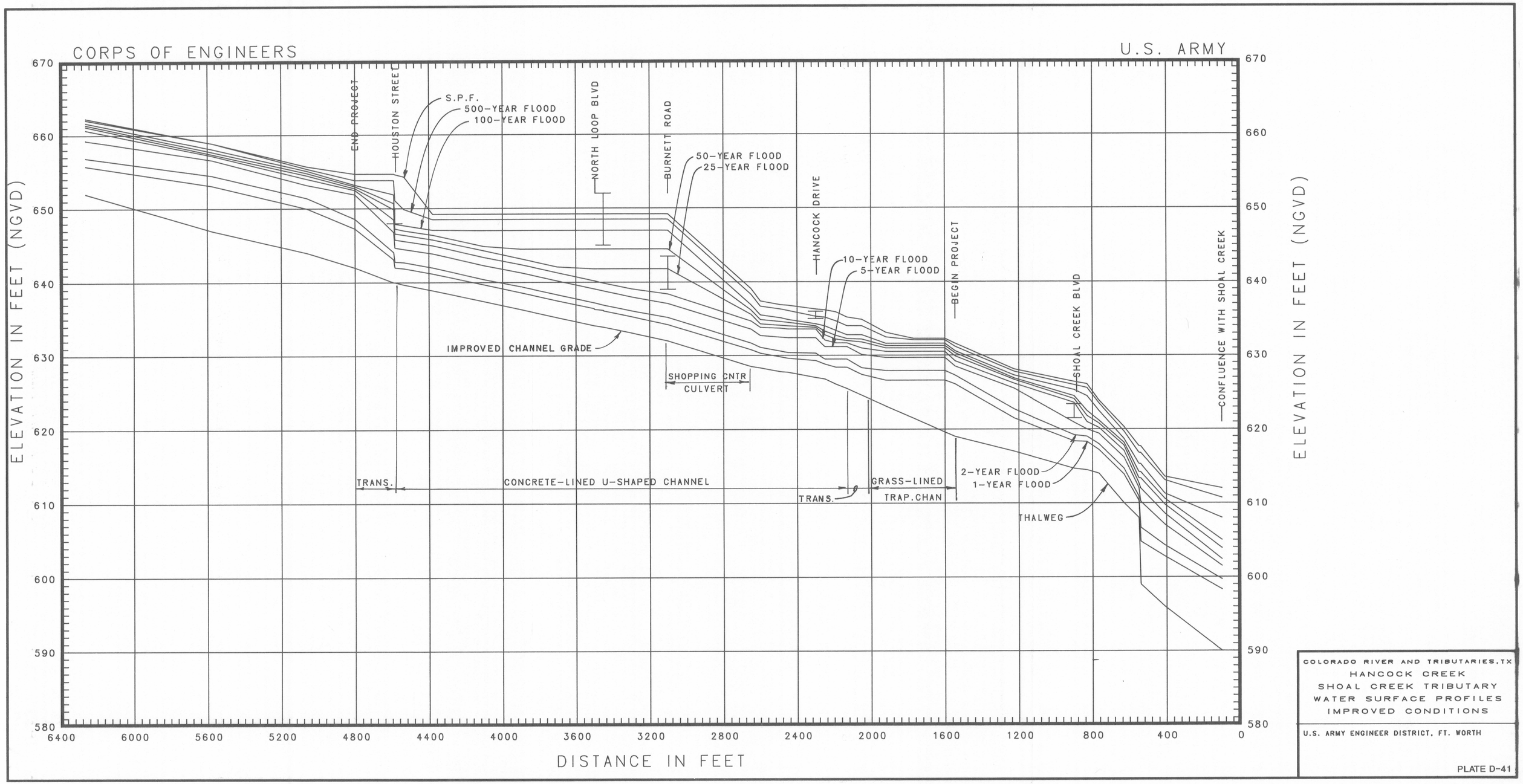
PLATE D-39



COLORADO RIVER AND TRIBUTARIES, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

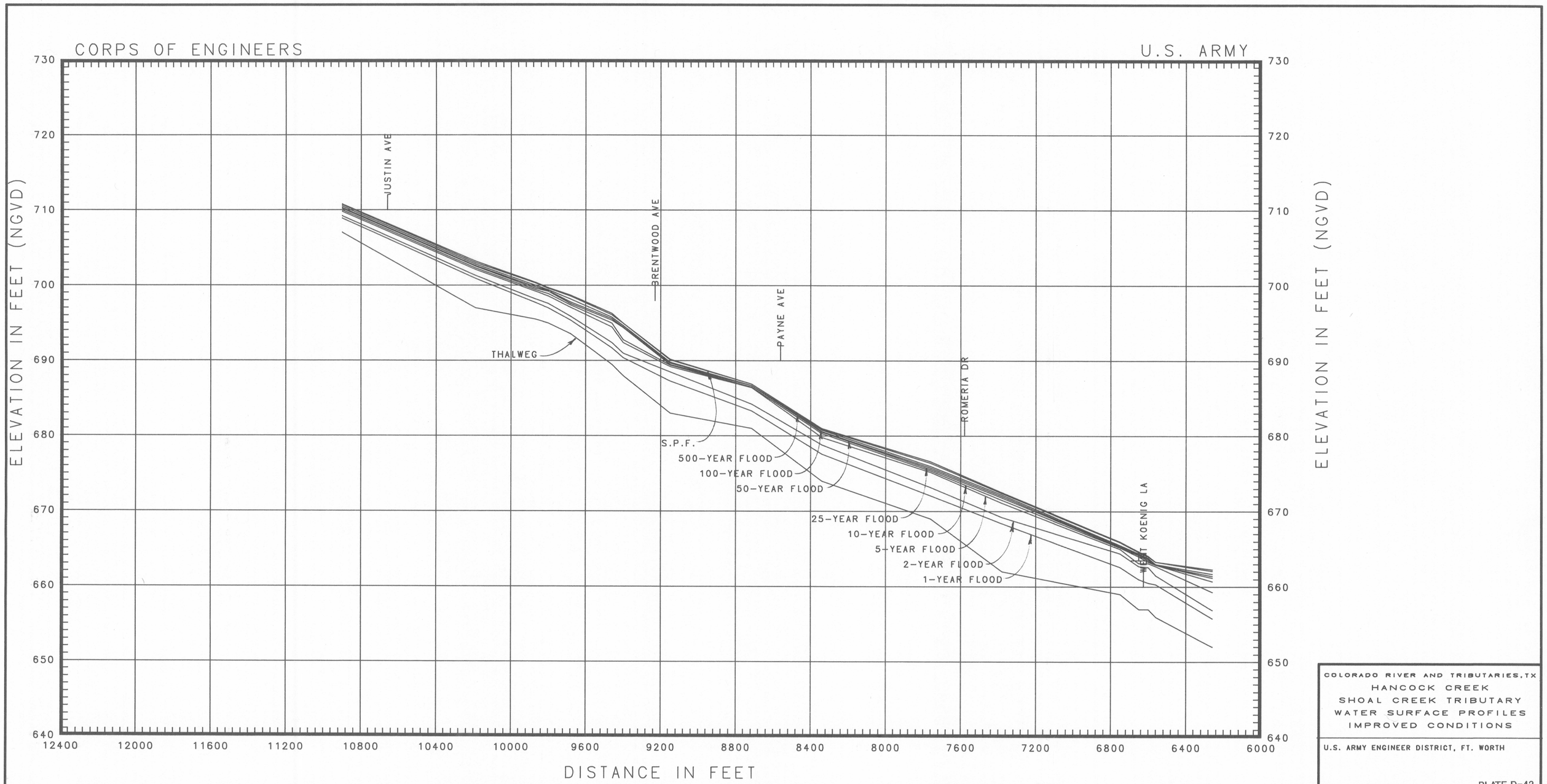
PLATE D-40



COLORADO RIVER AND TRIBUTARIES, TX
HANCOCK CREEK
SHOAL CREEK TRIBUTARY
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-41



COLORADO RIVER AND TRIBUTARIES, TX
HANCOCK CREEK
SHOAL CREEK TRIBUTARY
WATER SURFACE PROFILES
IMPROVED CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE D-42

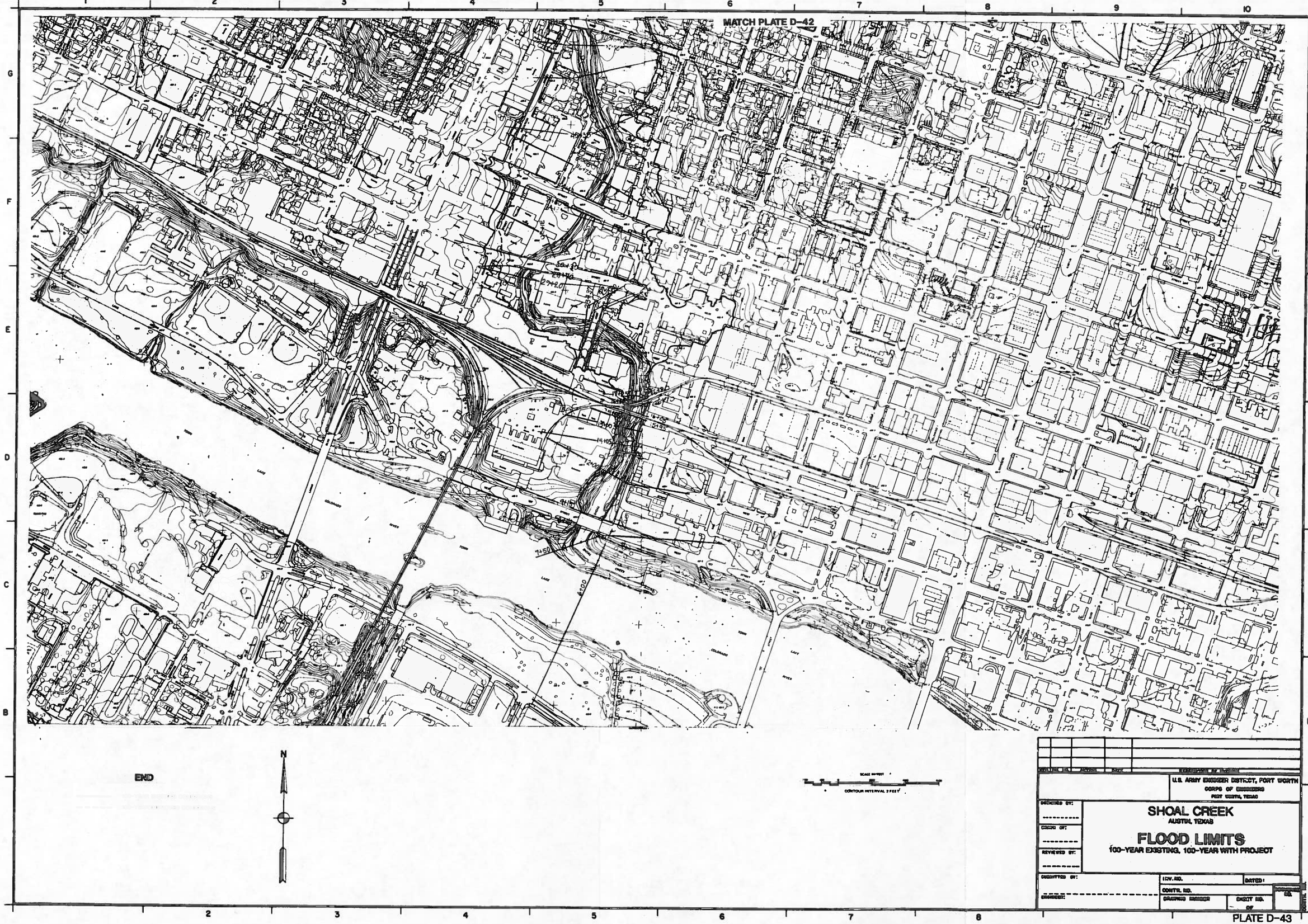

MATCH PLATE D-42
END
N
CONTOUR INTERVAL 2 FEET
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS
SHOAL CREEK
AUSTIN, TEXAS
FLOOD LIMITS
100-YEAR EXISTING, 100-YEAR WITH PROJECT
DESIGNED BY:
DRAWN BY:
REVIEWED BY:
SUBMITTED BY:
ENGINEER:
INV. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
OF

PLATE D-43

LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SUBMITTED BY:

ENGINEER:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

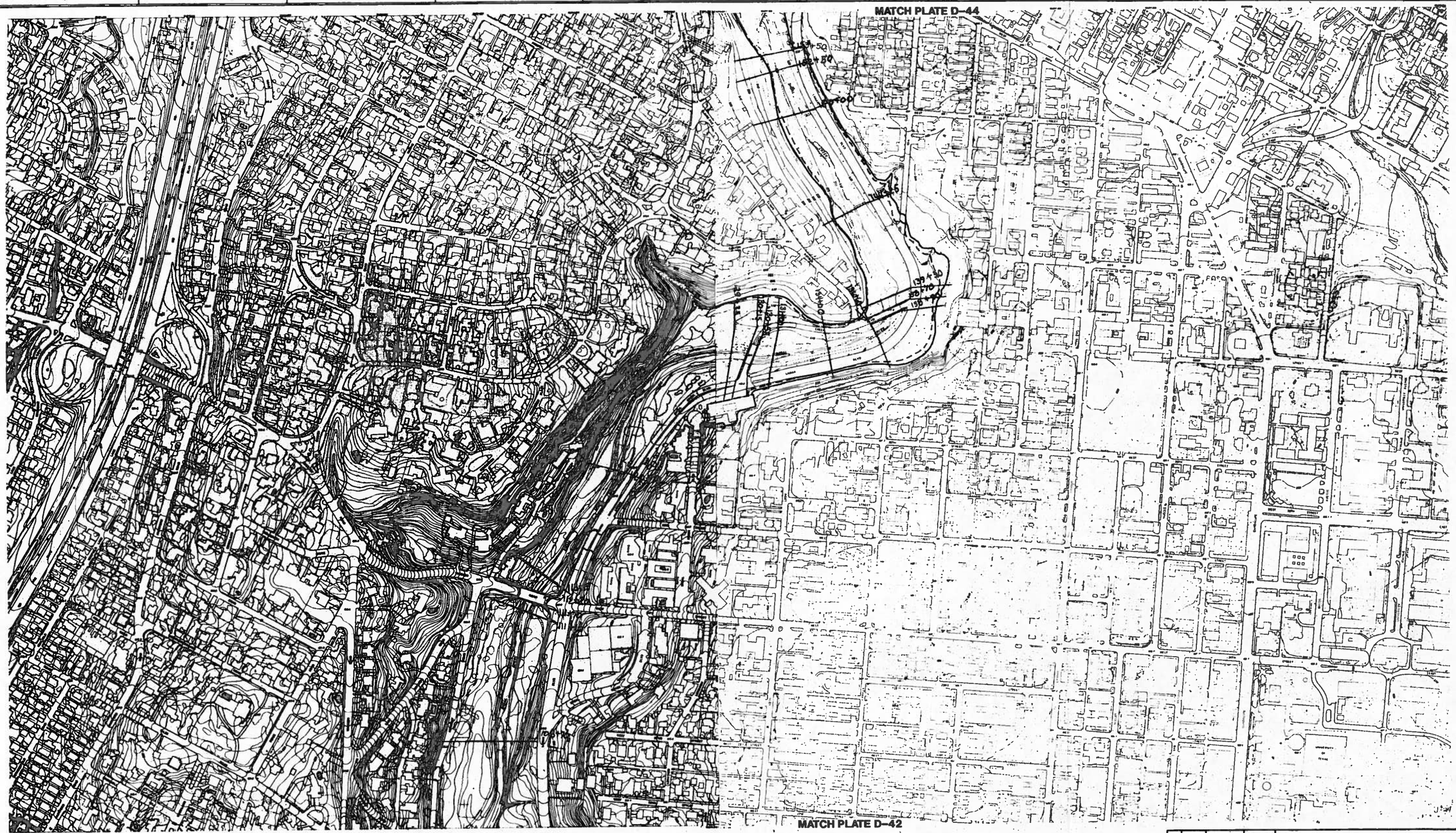
INV. NO.

DATED:

CONTR. NO.

DRAWING NUMBER

SHEET NO.



LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:
DRAWN BY:
REVIEWED BY:
SUBMITTED BY:
ENGINEER:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO. 97

END

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:
DRAWN BY:
REVIEWED BY:
SUBMITTED BY:
ENGINEER:

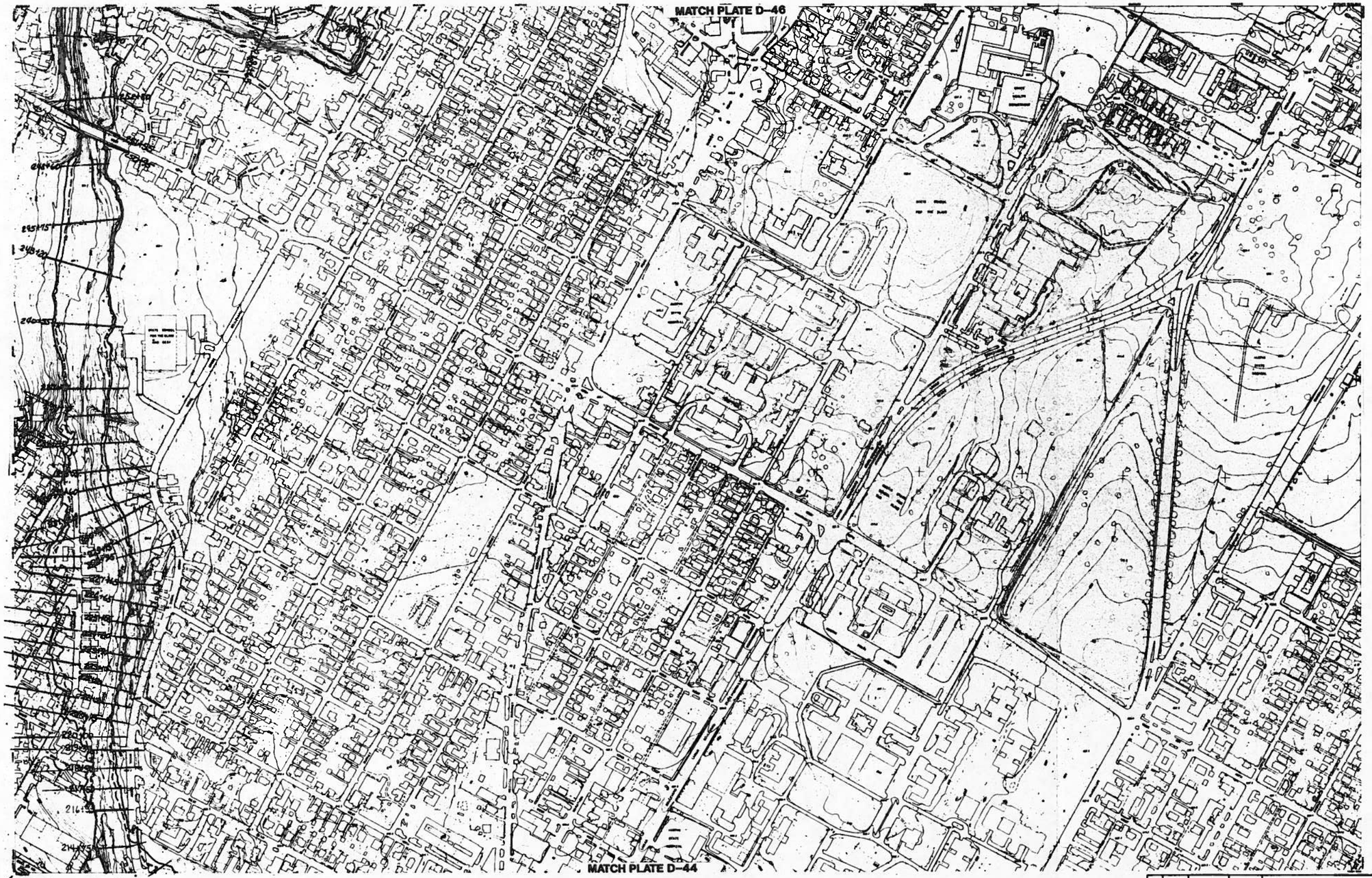
SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.
DATED:
CONTR. NO.
DRAWING NUMBER
SHEET NO.
OF



LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SUBMITTED BY:

ENGINEER:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.

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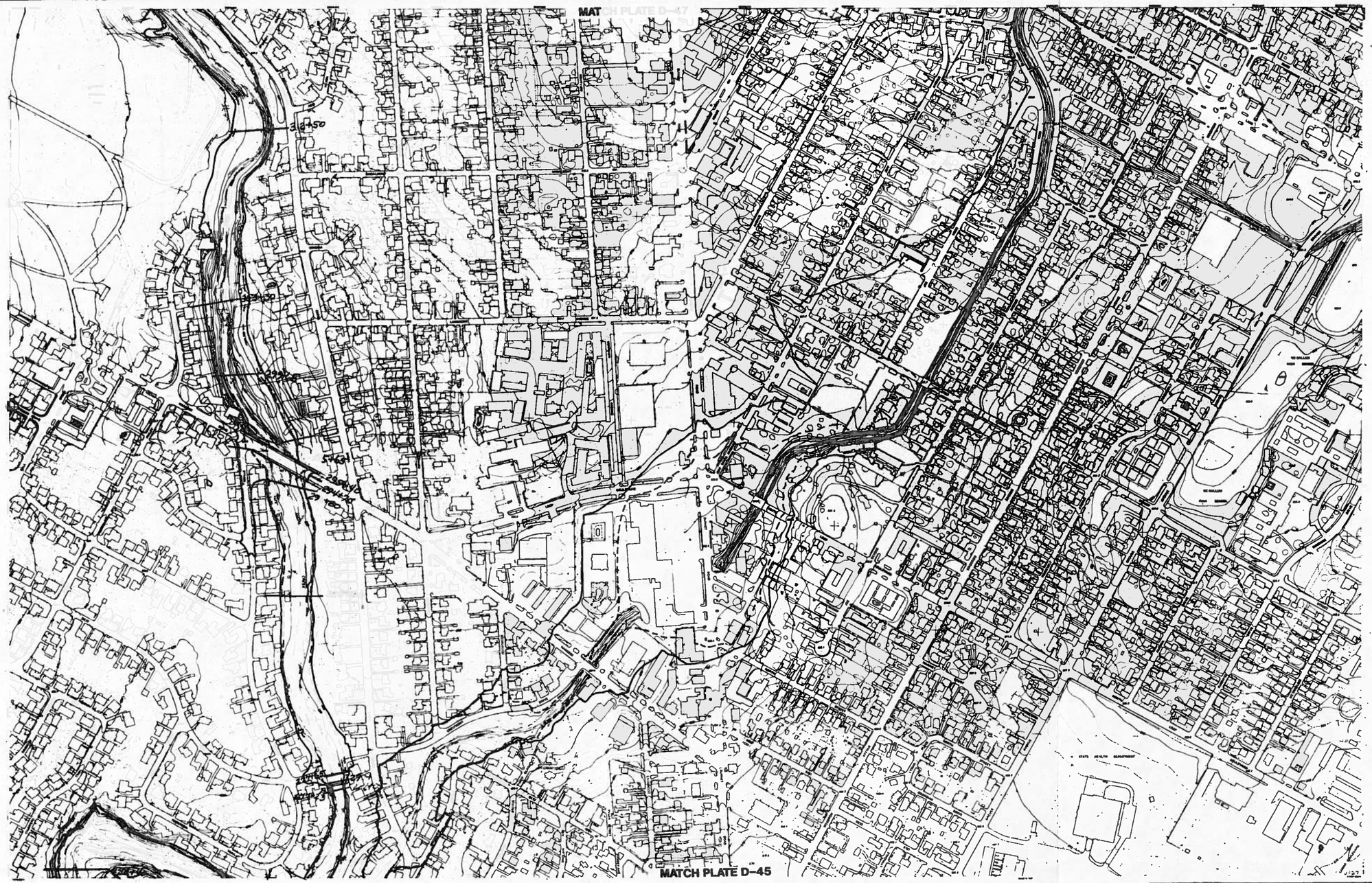
OF



LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

DATE	NO.	REVISION	BY	DESCRIPTION OF REVISION

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SUBMITTED BY:

ENGINEER:

SHOAL CREEK
AUSTIN, TEXAS

FLOOD LIMITS
100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.

DATED:

CONTR. NO.

DRAWING NUMBER

SHEET NO. OF

PI ATF D-48

LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SUBMITTED BY:

ENGINEER:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.

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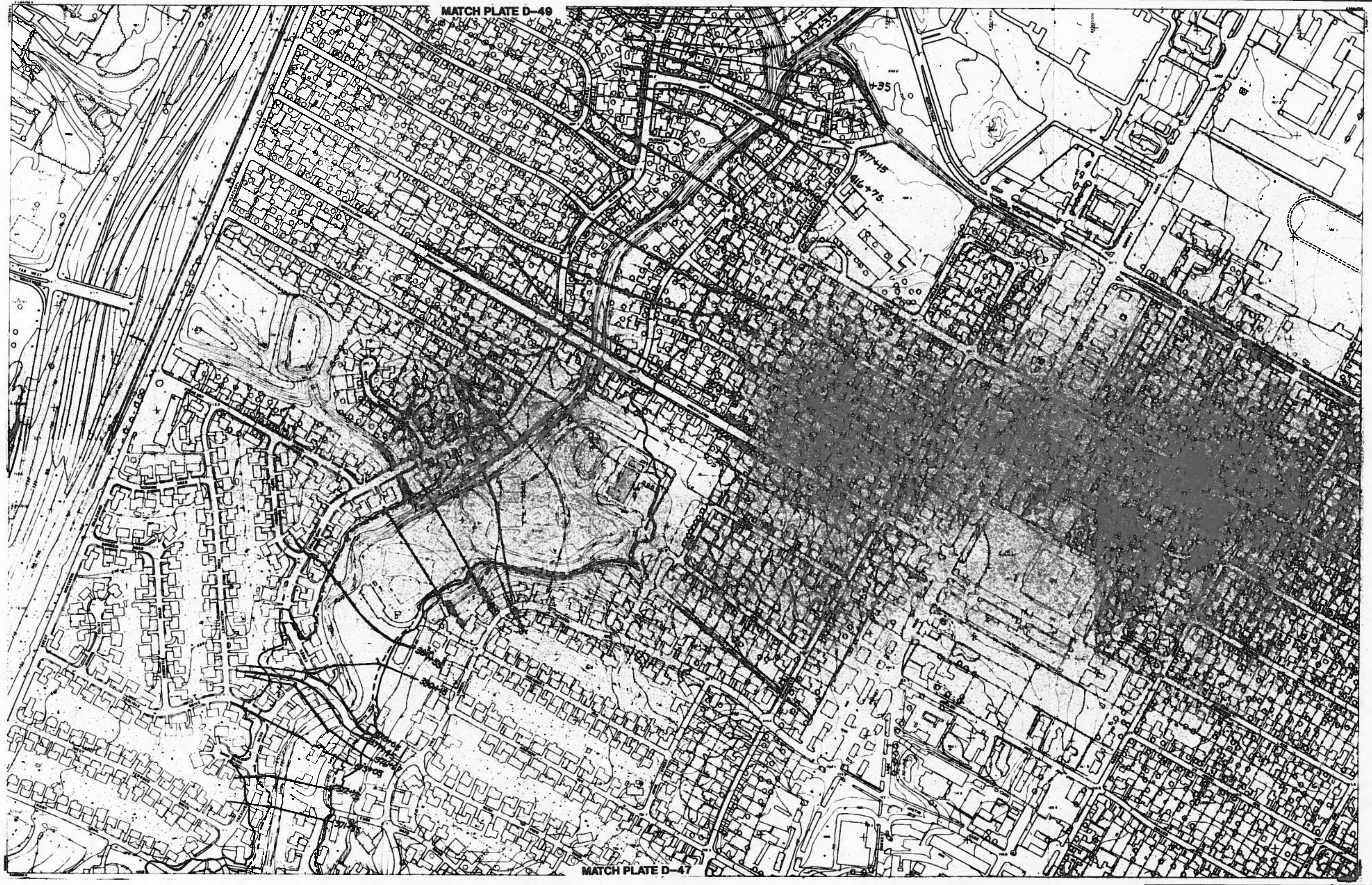
OF



LEGEND

- ——— 100-YEAR EXISTING CONDITIONS
- – – – – 100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

SUBMITTED BY:

ENGINEER:

INV. NO.

DATED:

CONTR. NO.

SHEET NO.

LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:
DRAWN BY:
REVIEWED BY:
SUBMITTED BY:
ENGINEER:

SHOAL CREEK
AUSTIN, TEXAS

FLOOD LIMITS
100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO. | DATED:
CONTR. NO.
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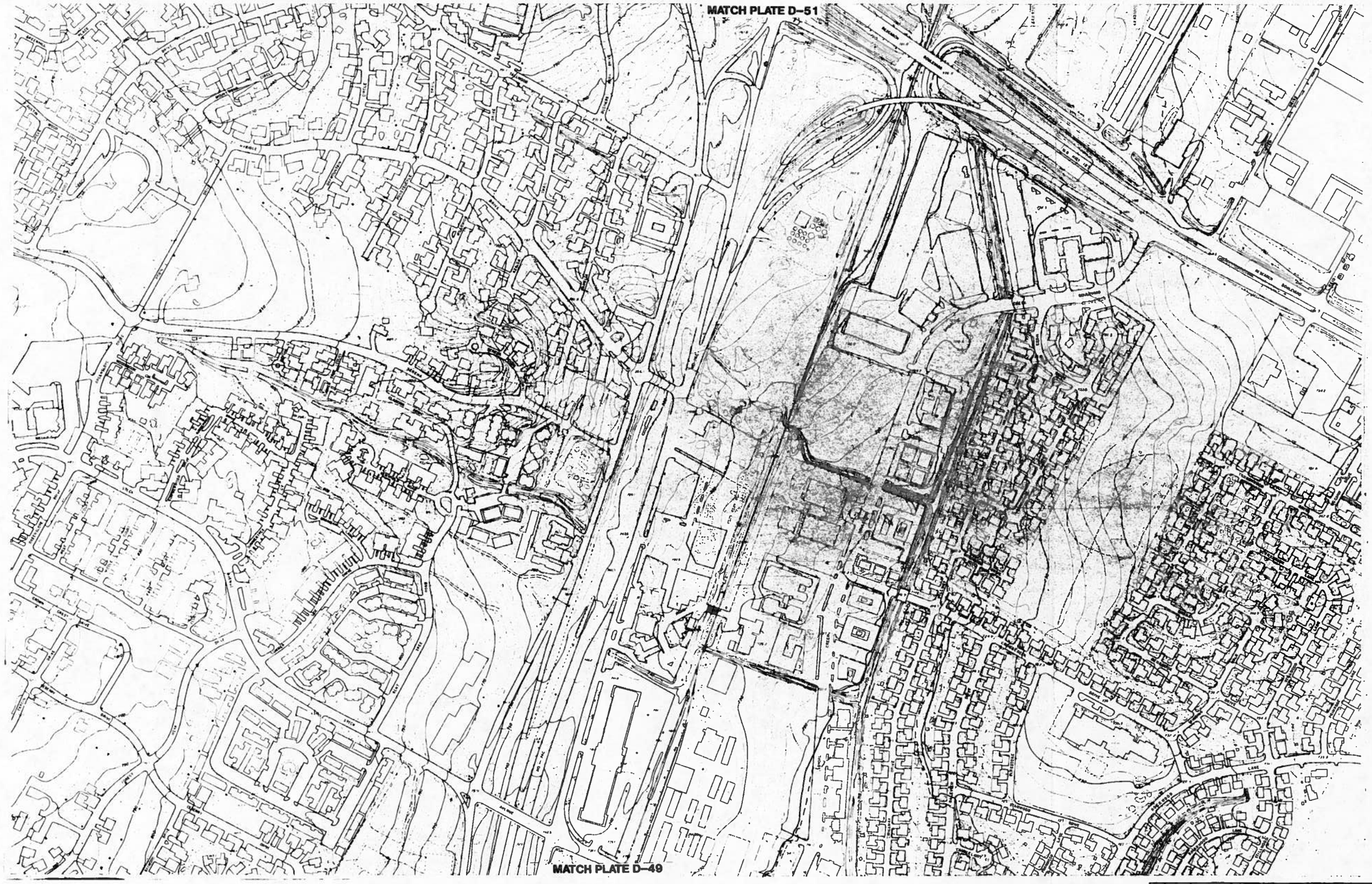

LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:
DRAWN BY:
REVIEWED BY:
SUBMITTED BY:
ENGINEER:

SHOAL CREEK
AUSTIN, TEXAS

FLOOD LIMITS
100-YEAR EXISTING, 100-YEAR WITH PROJECT

INV. NO.
DATED:
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DRAWING NUMBER
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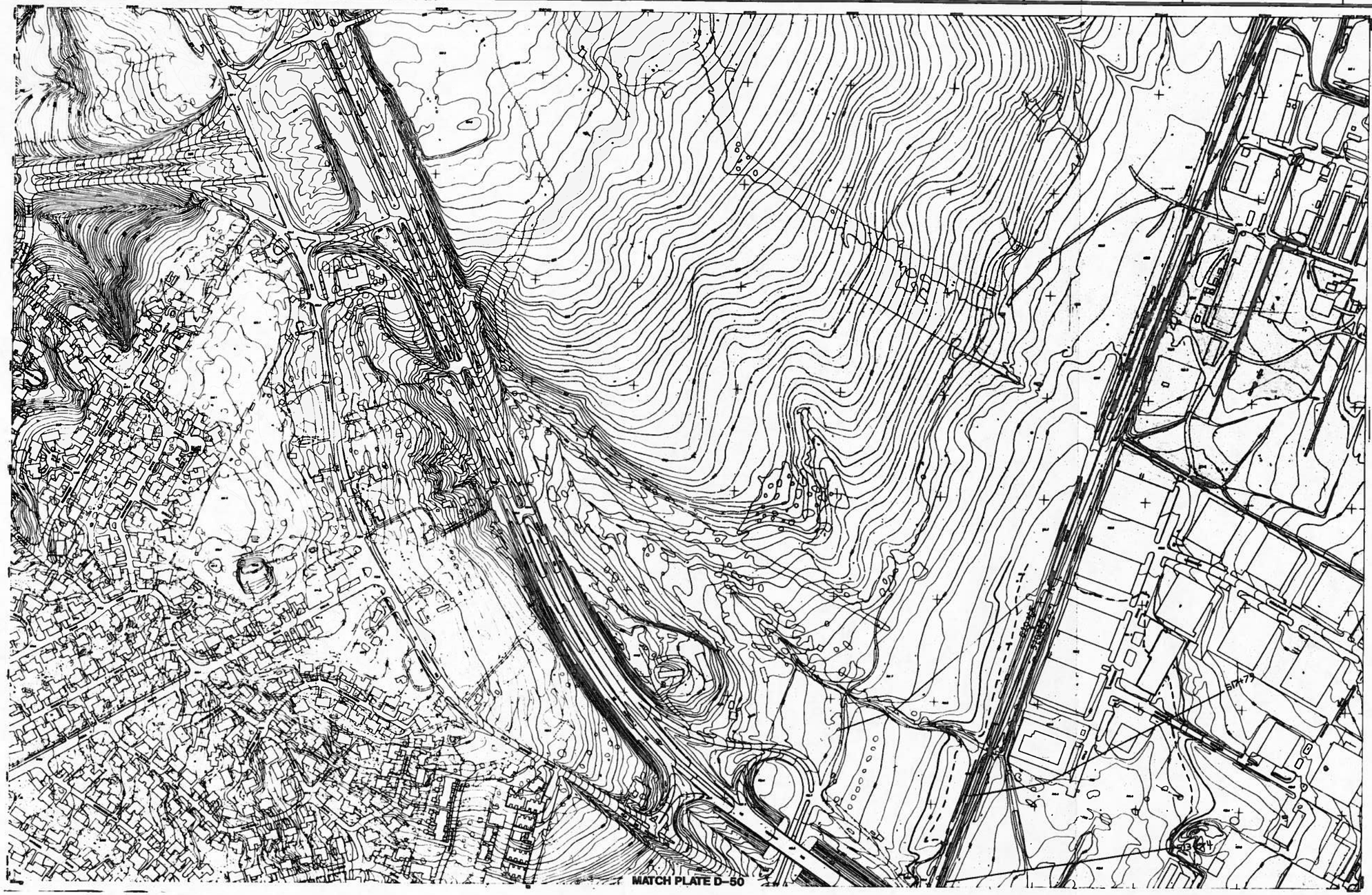
OF



LEGEND

100-YEAR EXISTING CONDITIONS

100-YEAR IMPROVED CONDITIONS

N

SCALE IN FEET

CONTOUR INTERVAL 2 FEET

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

DESIGNED BY:

DRAWN BY:

REVIEWED BY:

SUBMITTED BY:

ENGINEER:

SHOAL CREEK

AUSTIN, TEXAS

FLOOD LIMITS

100-YEAR EXISTING, 100-YEAR WITH PROJECT

SOL. NO.

DATED:

CONTR. NO.

DRAWING NUMBER

SHEET NO.

OF

APPENDIX E

ECONOMIC ANALYSIS

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APPENDIX E

SHOAL CREEK
AUSTIN, TEXAS
ECONOMIC ANALYSIS

INTRODUCTION

General

This section of the report documents the economic investigations and analyses made to determine the extent and need for flood control on flood plain lands along Shoal Creek and Hancock Creek at Austin, Texas. As part of these activities:

o Field surveys were conducted to identify the numbers and types of property, as well as the value of the investment affected by flooding;

o Calculations were performed to estimate the existing annual and the resulting annual benefits attributable to the recommended plan;

o Future probable growth trends for flood plain lands were assessed to determine their likely effect on future damages and benefits.

Purpose

The principal purpose of these economic analyses was to identify the extent of the flood problem and on a comparable basis with other plans evaluate the recommended plan of improvement. In order to accomplish this, it was necessary:

o To determine the magnitude of the existing flood problem;

o To prepare estimates of the benefits that could accrue to the plans of improvement investigated; and

o To ascertain whether future probable conditions in the affected study area could change enough to significantly influence the damages as well as potential benefits over the life of the project.

Scope

The economic analysis conducted followed procedures set forth in Water Resources Council's Principles and Guidelines (July 1983). Key assumptions incorporated into these economic analyses are the following:

o Estimates of existing flood damages and benefits presented herein reflect February 1991 prices and level of development.

o The year 1996 was assumed to be the first year of operation for the plans investigated.

o A 100-year project life was assumed, extending from 1996 to 2096.

o Probable future conditions gave consideration to anticipated growth from 1989 through 2096.

o The current FY 1991 Federal interest rate of 8-3/4 percent was applied to convert undiscounted future damages and benefits to average annual equivalent values.

WITHOUT PROJECT CONDITIONS

IDENTIFYING THE FLOOD PROBLEM

The field investigations undertaken, and the procedures used to identify the flood damages along Shoal Creek and Hancock Creek are described in the following paragraphs. The area surveyed included all flood prone properties lying within the SPF limits along 11.6 river miles of the two streams.

Flood Profiles and Flood Outlines

A full range of water surface profiles up to the standard project flood event based on existing stream conditions were developed. These profiles, which include the recent improvements made by the city, aided in delineating the flood plain limits, establishing the vertical control, and determining the relationship of damageable properties to both elevation and frequency of flood occurrence.

Reach Determinations

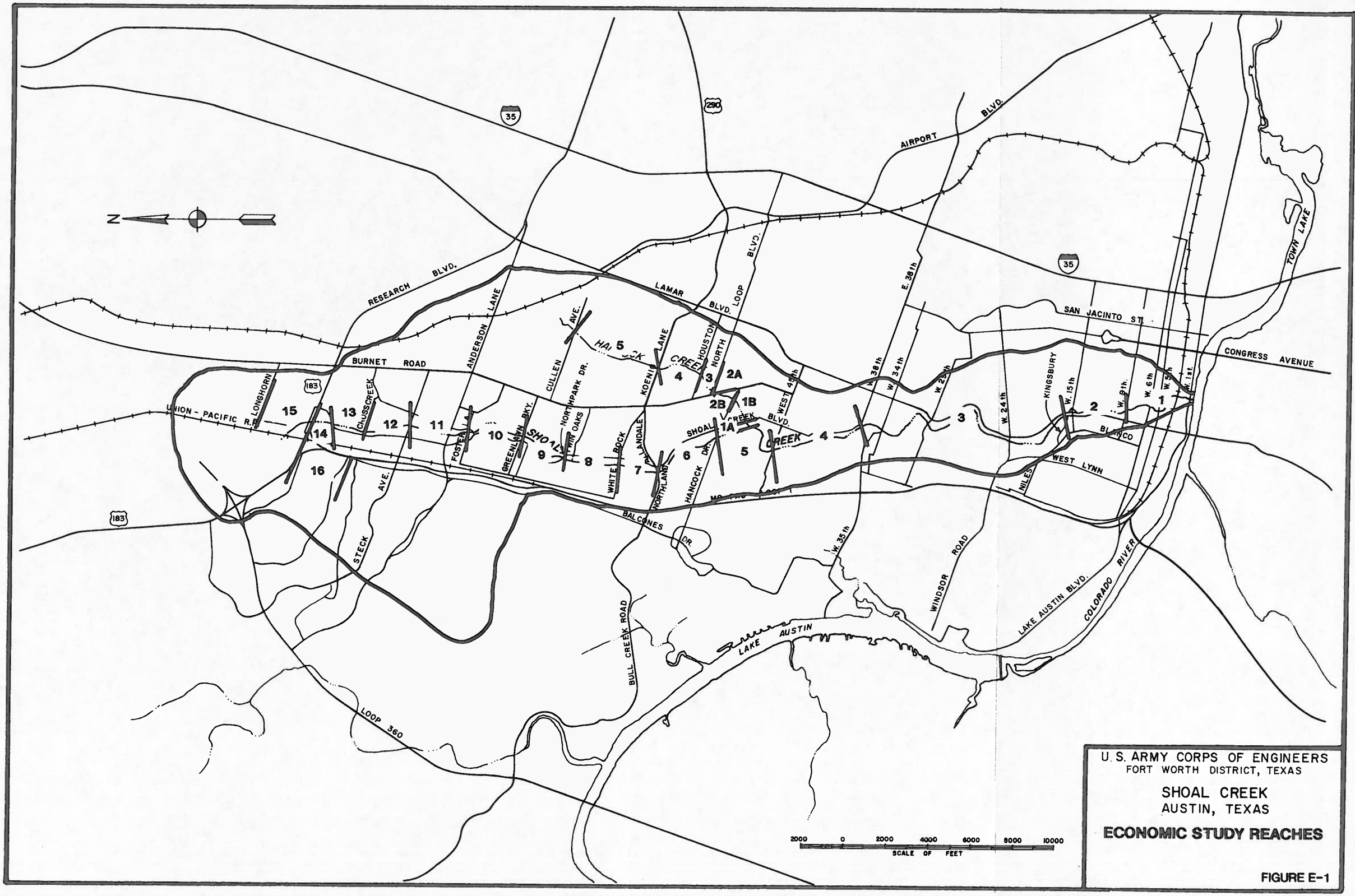
The affected study area was subdivided into 23 study reaches. The determination of reaches gave consideration to:

o Continuity of water surface profiles;

o Homogeneity of urban development in flood plain lands; and

o Isolation of significant potential damage centers from areas of minimal or negligible damage potential.

The reporting reaches utilized in the study are shown in figure E-1. Table E-1 provides a description of the linear limits of the reaches.



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

SHOAL CREEK
AUSTIN, TEXAS

ECONOMIC STUDY REACHES

FIGURE E-1

TABLE E-1

REACH DESCRIPTION

Reach	Station From (in feet)	Station To (in feet)	Ending Location
			SHOAL CREEK
1	0+00	47+22	West 9th Street
2	47+22	81+40	Above junction of Kingsbury and Shoal Creek
3	81+40	208+25	West 38th Street
4	208+25	251+50	West 45th Street
5	251+50	295+70	Hancock Drive
6	295+70	329+95	Northland Drive
7	329+95	349+95	White Rock Drive
8	349+95	378+08	Junction of Shoal Creek Blvd and Northpark Dr
9	378+08	402+35	Greenlawn Parkway
10	402+35	431+51	Foster Lane
11	431+51	460+64	Steck Avenue
12	460+64	482+04	Cross Creek Drive
13	482+04	497+44	Shoal Creek Blvd
14	497+44	507+69	Hwy US 183
15	507+69	520+00	Longhorn Blvd
16	481+74	507+69	US Hwy 183 and south of Cross Creek Drive (overflow)
			HANCOCK CREEK
1A	0+00	8+65	Confluence to Shoal Creek Blvd
1B	8+65	22+80	Hancock Drive
2B	22+80	30+00	Burnet Road
2A	30+00	34+75	North Loop Blvd
3	34+75	45+55	Houston Street
4	45+55	66+00	West Koenig Lane
5	66+00	109+00	Cullen Avenue

Field Investigations

A field survey was made of flood plain lands along Shoal Creek and Hancock Creek in March 1984 and in October 1986. As part of these activities, an inventory was made of the current types and level of flood plain development. This included identification of the numbers and types of structures within their SPF limits, existing land use patterns, and establishment of major damage categories. The properties were classified according to the major damage categories shown in table E-2.

TABLE E-2

DAMAGE CATEGORIES

Damage Category	:	Activity Description
Residential		Single and multi-family dwellings
Commercial		Retail and wholesale businesses
Public		Public buildings, city hall, fire stations, etc. Semi-public facilities, churches, recreation centers, etc.
Industrial		Manufacturing facilities
Transportation		Warehouses, streets, highways, and bridges
Communication and Utilities		Electrical, gas, telephone, and sewer facilities, and buildings
Public Health and Relief		Municipal services (police, fire, and service assistance required during flood emergencies)

A determination was also made of the current market value of flood plain investment. Estimates of the current market value of residential investment were developed through the assistance of local real estate firms and area developers who provided information on prior sales and current sale prices of houses in the study area. Existing residential contents were estimated to be 50 percent of the structure value. Smaller commercial, manufacturing and public structures were evaluated in a similar manner. Content values were prepared on the basis of structure-to-content ratios determined from previous studies. For larger more costly properties, personal interviews were conducted with owners, managers, and plant officials to obtain information on the investment and damage susceptibility of the flood plain properties.

MAGNITUDE AND EXTENT OF THE FLOOD PROBLEM

Flood Loss History

Over the years, the Austin area has experienced extensive damages from floodflows along Shoal Creek. Flash flooding has periodically occurred with the more damaging storms recorded in April 1915 (35 or more lives reported lost), September 1921, November 1974, April 1975, and the most recent, May 1981 (13 lives lost due to floodwaters). During May 24-25, 1981, the city of Austin recorded 13 deaths due to drowning with 5 of these deaths occurring on Shoal Creek.

The most devastating flood on Shoal Creek was caused by the May 1981 storm. This storm produced rainfall rates in the 4- to 6-inch per hour range. Rapidly rising floodwaters trapped many families in their homes. This rapid, unexpected runoff also stranded numerous automobiles including the occupants. Many of the automobiles were swept downstream into the main flows, blocking bridges and, in turn increasing the severity of flooding. The May 1981 storm caused an estimated $30 million worth of damages and affected 708 families. Although Shoal Creek was not the only stream to flood, it was the most affected due to the extensive urban development.

Structures Identified

A total of 922 structures were identified within the SPF flood plain limits of Shoal Creek. Of this total, 725 structures are residential dwellings with the heaviest concentrations occurring in reaches 8 through 13. Residential structures comprise about 79 percent of the total number of flood plain properties. Typically, these consist of single story brick and wood frame structures. The second most significant concentration were commercial properties numbering 158 structures situated mainly in reaches 1, 2, 11, 12, and 16. Commercial structures make up about 17 percent of the properties found in the flood plain. This group is comprised of small retail and service establishments such as restaurants, service stations, convenience stores, small grocery stores, and various other small retail outlets, along with large shopping centers and office buildings. There are 20 industrial, 11 transportation, 6 public, and 2 communication/utility facilities located in the study area (4 percent of the total).

On Hancock Creek, the major tributary of Shoal Creek, 419 structures were counted within the SPF limits. Of these, 363 were found to be residential dwellings, 46 commercial structures, and 10 public or transportation-utility related facilities. The greatest concentration of residential structures are in reaches 3 through 5 with 310 structures or 74 percent. Reach 2B contains the most commercial properties with 18 facilities or about 39 percent of the total. There are two public facilities, as well as eight transportation facilities located in the study area which account for about 1 percent of the total structures. A summary of data for Shoal Creek and Hancock Creek is presented in table E-3.

Investment Identified

The estimated value of flood plain investments located in the affected study area is displayed in table E-4. As shown, investment within the Shoal Creek SPF limits totals over $321 million based on April 1990 prices and level of development. This value includes structures, contents, inventories, and equipment, exclusive of land costs. The largest concentration of flood plain investment is in residential property valued at over $157 million or about 49 percent of the total. Most of this, or about 74 percent of the residential total, is found in reaches 8, 9, 10, 11, and 12. Commercial properties are the second largest concentration valued at over $89 million, followed by industrial at approximately $27

TABLE E-3
NUMBER OF STRUCTURES WITHIN SPF FLOOD PLAIN BY REACH AND TYPE
(February 1991 prices and level of development)

Reach	Residential Single Family	Residential Multi-Family	Commercial	Public	Industrial	Transportation	Communications and Utilities	Total	% of Total
SHOAL CREEK									
1	13	4	43	0	4	1	0	65	(07)
2	17	1	44	5	1	1	1	70	(07)
3	3	1	4	0	0	1	1	10	(01)
4	21	0	3	0	1	0	0	25	(03)
5	23	0	0	0	0	0	0	23	(02)
6	14	0	0	0	0	0	0	14	(01)
7	43	0	0	0	0	0	0	43	(05)
8	120	0	0	0	0	0	0	120	(13)
9	63	0	3	1	0	0	0	67	(07)
10	143	37	1	0	0	0	0	181	(19)
11	67	2	32	0	1	0	0	101	(11)
12	125	1	13	0	0	0	0	139	(15)
13	45	0	0	0	0	0	0	45	(05)
14	0	0	2	0	0	0	0	2	(0)
15	0	0	2	0	4	7	0	13	(01)
16	1	6	11	0	9	1	0	28	(03)
Subtotal	698	52	158	6	20	11	2	946	
Percent of Total	(74)	(5)	(17)	(1)	(2)	(1)	(0)*		(100)
HANCOCK CREEK									
1A	15	0	0	0	0	0	0	15	(04)
1B	35	0	4	0	0	0	0	39	(09)
2A	1	0	7	0	0	0	0	8	(02)
2B	0	2	18	1	0	0	0	21	(05)
3	17	14	8	0	0	1	0	40	(10)
4	145	8	5	0	0	7	0	165	(39)
5	126	0	4	1	0	0	0	131	(31)
Subtotal	339	24	46	2	0	8	0	419	
Percent of Total	(81)	(6)	(11)	(0)*	(0)*	(2)	(0)*		(100)
TOTAL	1,037	51	204	8	20	19	2	1,341	
Percent of Total	(77)	(4)	(15)	(1)	(2)	(1)	(0)*		(100)

* Less than one percent.

TABLE E-4

ESTIMATED VALUE OF EXISTING INVESTMENT WITHIN SPF FLOOD PLAIN
(February 1991 prices and level of development)

Reach	Residential Single Family	Residential Multi-Family	Commercial	Public	Industrial	Transportation	Communication and Utilities	Total	% of Total
					SHOAL CREEK				
1	$ 1,138.8	$ 1,565.0	$20,413.1	$ 0.0	$ 1,859.2	$ 1,249.9	$ 1,572.0	$ 27,798.0	(09)
2	2,529.3	3,991.7	14,282.2	2,000.3	56.0	1,172.6	2,117.7	26,149.8	(08)
3	771.1	588.0	2,128.0	0.0	0.0	182.2	1,787.7	5,457.0	(02)
4	2,983.2	0.0	5,107.2	0.0	336.0	421.3	530.9	9,378.6	(03)
5	4,174.0	0.0	0.0	0.0	0.0	208.7	263.0	4,645.7	(01)
6	2,449.8	0.0	0.0	0.0	0.0	122.5	154.3	2,726.6	(01)
7	6,964.9	0.0	0.0	0.0	0.0	348.2	438.8	7,751.9	(02)
8	21,729.9	0.0	0.0	0.0	0.0	1,086.5	1,369.0	24,185.4	(08)
9	11,319.5	0.0	666.4	33.6	0.0	601.0	757.2	13,377.7	(04)
10	26,690.3	16,964.6	67.2	0.0	0.0	2,186.1	2,754.5	48,662.7	(15)
11	8,857.9	11,022.5	6,183.5	0.0	315.2	1,318.9	1,661.9	29,359.9	(09)
12	18,532.4	1,020.7	3,696.0	0.0	0.0	1,162.4	1,464.7	25,876.2	(08)
13	6,714.5	0.0	0.0	0.0	0.0	335.8	423.0	7,473.3	(02)
14	0.0	0.0	2,856.0	0.0	0.0	142.8	179.9	3,178.7	(01)
15	0.0	0.0	6,496.0	0.0	4,897.4	12,876.2	717.8	24,987.4	(08)
16	136.1	7,346.0	27,540.8	0.0	19,600.0	2,792.7	3,441.2	60,856.8	(19)
Subtotal	$114,991.7	$42,498.5	$ 89,436.4	$2,033.9	$27,063.8	$26,207.8	$19,633.6	$321,865.7	
Percent of Total	(36)	(13)	(28)	(01)	(08)	(08)	(06)		(100)
					HANCOCK CREEK				
1A	2,805.6	0.0	0.0	0.0	0.0	140.3	176.7	3,122.6	(03)
1B	3,822.0	0.0	1,260.0	0.0	0.0	254.1	320.2	5,656.3	(06)
2A	75.6	0.0	1,258.9	0.0	0.0	56.2	70.8	1,461.5	(02)
2B	0.0	10,718.4	8,733.4	406.8	0.0	992.9	1,251.0	22,102.5	(24)
3	1,579.2	17,001.6	2,564.8	0.0	0.0	1,064.0	1,331.7	23,541.3	(25)
4	13,398.0	2,301.6	739.2	0.0	0.0	972.0	1,035.7	18,446.5	(20)
5	12,961.2	0.0	812.0	3,446.2	0.0	895.0	1.127.7	19,242.1	(20)
Subtotal	$ 34,641.6	$30,021.6	$ 15,368.3	$3,853.0	$ 0.0	$ 4,374.5	$ 5,313.8	$ 93,572.8	
Percent of Total	(37)	(32)	(16)	(04)	(00)	(05)	(06)		(100)
TOTAL	$149,633.3	$72,520.1	$104,804.7	$5,886.9	$27,063.8	$30,582.3	$24,947.4	$415,438.5	

* Less than one percent.

million, transportation at $26 million, and communication and utilities at about $20 million. Public property investment accounts for one percent, valued at about $2 million.

Investment within the Hancock Creek SPF limits is estimated to be over $93 million based on April 1990 prices and level of development. This investment includes the value of structures, contents, inventories, and equipment, but excludes land costs. The largest investment is in residential dwellings, valued at over $64 million, or 69 percent of total. These residential structures are located primarily in reaches 2B, 3, 4 and 5, each accounting for 20 to 25 percent of the total residential investment. The second largest investment is in commercial structures, at over $15 million, located primarily in reaches 1B, 2A, 2B, and 3. Transportation, communications and utilities investment is over $9 million, and public facilities investment is nearly $4 million.

Damage Susceptibility

Depth damage relationships for the different types of flood plain properties were determined using the data collected during the field investigations and information obtained in prior field surveys. In establishing these relationships for each property type, consideration was given to such factors as design of the structure, the type of equipment contained in the structure, and the damage susceptibility of the contents contained in each structure.

Stage-Damage Calculations

Stage-damage relationships were developed at 1-foot intervals from the 1-year event (100 percent annual probability of exceedance) to the SPF event. This was accomplished by applying the appropriate damage susceptibility coefficient for each successive foot of flooding from the zero damage point of an affected structure to the SPF event. Damage to the various activities at each stage of flooding were then summed to produce a stage-damage relationship. Depth-damage relationships by development type are shown in table E-5.

Single Occurrence Flood Losses

It is estimated that an SPF flood event in the Shoal Creek flood plain could potentially cause property damages of over $95 million. This represents a loss of about 30 percent of the total investment along the creek. Comparatively, the 100-year event could produce losses totalling over $58 million or about 18 percent of the total flood plain value. Hancock Creek would sustain losses of nearly $24 million from an SPF flood event and about $18 million from the 100-year event, or 25 and 19 percent respectively of the total flood plain investment. Estimates of flood losses for selected single occurrence events, by reach, are presented in table E-6.

TABLE E-5
DEPTH-DAMAGE RELATIONSHIPS BY DEVELOPMENT TYPE
(PERCENT DAMAGE BY DEPTH OF FLOODING)

CRV. NUM.	DESCRIPTION		DEPTH OF FLOODING RELATIVE TO FINISHED FLOOR(FEET):																			
			-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
S0	GENL. RES.	STRUCTURE	0	0	0	0	10	21	28	34	43	48	51	54	58	61	63	65	69	71	75	79
C0	GENL. RES	CONTENTS	0	0	0	0	7	38	55	66	73	78	82	84	87	88	88	88	89	90	93	96
S1	1 STORY RES.	STRUCTURE	0	0	0	0	10	21	27	32	37	43	46	50	54	58	60	63	67	70	74	79
C1	1 STORY RES.	CONTENTS	0	0	0	0	8	42	60	71	77	82	85	86	87	88	88	88	89	90	93	96
S2	1-1/2 STORY RES.	STRUCTURE	0	0	0	0	10	28	35	41	43	46	48	49	50	50	50	51	51	52	53	55
C2	1-1/2 STORY RES.	CONTENTS	0	0	0	0	2	22	36	45	57	66	71	77	79	82	84	86	87	89	90	91
S3	2 STORY RES.	STRUCTURE	0	0	0	0	5	21	27	31	34	37	39	40	40	42	44	47	49	52	55	58
C3	2 STORY RES.	CONTENTS	0	0	0	0	4	24	34	40	47	53	56	58	58	58	61	66	68	76	81	86
S4	MOBILE RES.	STRUCTURE	0	5	5	13	14	19	31	54	93	96	96	97	97	97	98	98	98	98	98	98
C4	MOBILE RES.	CONTENTS	0	0	0	0	3	23	36	43	55	66	78	86	100	100	100	100	100	100	100	100
S5	HIGH RISE RES.	STRUCTURE	0	0	0	0	0	1	2	3	5	7	8	10	12	18	28	41	48	52	56	57
C5	HIGH RISE RES.	CONTENTS	0	0	0	0	1	2	5	8	10	12	13	13	14	26	38	52	64	78	84	88
S6	1 STORY APT.	STRUCTURE	0	0	0	0	5	18	25	30	34	38	41	43	46	48	50	52	54	55	57	59
C6	1 STORY APT.	CONTENTS	0	0	0	0	6	34	44	55	67	77	87	97	100	100	100	100	100	100	100	100
S7	2 STORY APT.	STRUCTURE	0	0	0	0	5	28	29	31	36	37	39	40	41	42	44	46	48	52	55	58
C7	2 STORY APT.	CONTENTS	0	0	0	0	4	24	34	40	47	53	56	58	58	58	61	66	68	76	81	86
SV	RES. VEHICLE	STRUCTURE	0	0	0	0	20	50	80	100	100	100	100	100	100	100	100	100	100	100	100	100
CV	RES. VEHICLE	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	AUTO DEALERSHIP	STRUCTURE	0	0	0	0	0	17	17	18	19	21	23	25	28	32	35	39	43	49	52	56
8	AUTO DEALERSHIP	CONTENTS	0	0	0	0	10	40	70	90	90	90	90	90	90	90	90	95	95	95	95	95
13	AUTO REPAIR	STRUCTURE	0	0	0	0	0	3	3	3	4	5	8	12	17	23	31	40	48	56	64	70
14	AUTO REPAIR	CONTENTS	0	0	0	0	23	53	74	100	100	100	100	100	100	100	100	100	100	100	100	100
99	DEPARTMENT STORE	STRUCTURE	0	0	0	0	0	3	7	7	7	9	11	14	17	20	23	26	30	33	37	40
100	DEPARTMENT STORE	CONTENTS	0	0	0	0	0	18	33	65	88	95	100	100	100	100	100	100	100	100	100	100

TABLE E-6
ESTIMATED SINGLE OCCURRENCE FLOOD LOSSES
FOR VARIOUS FREQUENCY EVENTS
(February 1991 prices)

Reach	SPF	500-Year	100-Year	50-Year	25-Year	10-Year	5-Year	2-Year	1-Year
				(in thousands of dollars)					
				SHOAL CREEK					
1	$ 9,996.0	$ 9,666.6	$ 8,800.2	$ 8,155.5	$ 7,756.3	$ 6,263.6	$ 258.0	$ 0.1	$ 0.0
2	11,486.2	10,937.1	9,630.0	8,372.5	7,476.6	4,817.8	3,724.2	1,793.6	0.1
3	888.8	788.8	492.5	135.4	72.1	0.0	0.0	0.0	0.0
4	2,337.9	2,066.3	1,175.7	422.4	182.0	0.2	0.0	0.0	0.0
5	1,497.1	1,047.6	549.3	353.9	305.5	251.7	182.4	57.8	3.9
6	1,027.9	997.9	702.4	452.8	294.8	88.4	31.7	0.2	0.0
7	2,048.6	1,731.4	1,181.2	669.1	392.8	111.8	23.1	0.1	0.0
8	6,958.2	6,502.5	4,444.1	3,119.9	2,420.0	1,333.0	1,005.4	600.8	175.0
9	3,349.0	2,209.0	375.7	0.1	0.0	0.0	0.0	0.0	0.0
10	11,684.5	8,980.5	5,638.1	4,098.4	3,113.3	1,503.4	446.8	5.7	0.0
11	7,192.6	6,745.3	5,627.1	4,956.1	4,444.8	3,413.2	2,290.7	313.2	0.1
12	6,832.9	6,296.1	4,474.7	2,730.2	1,895.8	1,134.7	747.4	36.3	0.0
13	1,375.1	1,134.6	773.7	662.6	588.6	231.3	130.3	509.0	0.1
14	350.9	325.4	86.0	28.7	0.0	0.0	0.0	0.0	0.0
15	8,113.6	8,070.8	6,937.1	4,771.6	4,662.3	4,332.6	2,923.4	1,972.5	1,255.6
16	8,898.4	8,667.6	7,513.6	7,052.0	6,821.2	6,352.2	2,406.4	1,775.0	1,621.9
Sub-total	$84,037.7	$76,167.5	$58,401.4	$45,981.2	$40,426.1	$29,833.9	$14,169.8	$7,064.3	$3,056.6
				HANCOCK CREEK					
1A	1,286.0	1,253.1	1,145.3	830.7	583.9	380.1	184.2	17.2	0.0
1B	1,341.4	1,173.6	921.9	749.8	577.9	418.9	238.6	122.6	78.3
2A	778.3	575.2	553.9	323.3	292.0	265.2	0.7	0.0	0.0
2B	7,178.6	6,543.3	6,430.4	5,600.7	3,850.8	2,181.5	11.2	0.0	0.0
3	7,094.3	5,723.9	4,556.3	3,253.4	2,867.3	1,658.1	0.0	0.0	0.0
4	4,697.2	4,280.2	3,237.8	2,612.4	2,307.5	1,698.0	832.0	2.8	0.0
5	1,552.0	1,483.0	1,107.3	996.0	662.0	404.2	308.0	60.1	0.0
Sub-total	$23,927.8	$21,032.3	$17,952.9	$14,298.2	$11,141.4	$ 7,006.0	$ 1,574.7	$ 202.7	$ 78.3
TOTAL	$109,965.5	$97,199.8	$76,354.3	$60,279.4	$51,557.5	$36,839.9	$15,744.5	$7,267.0	$ 3,134.9

Note: Numbers have been rounded.

Average Annual Damage Calculations

Estimates of average annual damages under existing conditions were calculated through an integration process. Generally, this was accomplished by multiplication of the mean damages (derived from the stage-damage function) by the differences in the exceedance probabilities for the same stages over the range of flooding. Average annual damages were calculated for properties that could be inundated up to the SPF event.

Existing Average Annual Flood Losses

Existing average annual flood loss in the Shoal Creek flood plain is estimated to be over $11.9 million, based on February 1991 prices and level of development. Of this amount, almost $6.0 million or 50 percent of these losses would occur to residential properties, located mainly in reaches 2 and 16, with 22 percent and 37 percent respectively. Commercial and industrial property damages account for 22 percent and 18 percent, of the property damages along Shoal Creek, respectively. Along Hancock Creek, existing average annual damages are estimated to be over $1.9 million based on February 1991 prices and level of development. Over $1.5 million or 78 percent of the total is residential with about 29 percent of the residential damages occurring in reach 4. Commercial and industrial property damages makeup 21 percent and 16 percent of the total damages along Hancock Creek, respectively. A summary of the existing average annual damages, by reach and type, is displayed in table E-7.

WITH PROJECT CONDITIONS

PLANS INVESTIGATED

A total of 15 structural alternatives were addressed in these investigations. This included examination of three sizes of channel plans six tunnel alternatives in various sizes, and six combination plans in various sizes. A description of each plan investigated is presented in table E-8.

NED Plan

Economic investigations in the latter stages of the study were primarily directed at calculating the flood control benefits that would be generated by the NED Plan of improvement. Several other plans were previously investigated but eventually dropped from further consideration following a logical sequence of economic efficiency and maximization of benefits and costs. With average annual benefits of about $12,400 million, the 14-foot combination plan which includes tunnel diversions at Northwest Park and 19th Street, and channelization on Shoal Creek and Hancock Creek, was selected as the NED Plan. An optimization curve is shown in figure E-2.

TABLE E-7
AVERAGE ANNUAL DAMAGES BY REACH AND TYPE
(February 1991 prices)

Reach	Residential Structures	Residential Contents	Commercial	Public	Industrial	Transpor-tation	Comm and Utilities	Public Health and Relief	Total	% of Total
	(thousands of dollars)									
					SHOAL CREEK					
1	$ 25.2	$ 18.9	$ 954.3	$ 0.0	$ 1.7	$ 19.9	$ 27.8	$ 65.0	$ 1,123.0	(9)
2	780.8	520.6	938.7	33.5	3.4	23.5	45.6	76.1	2,425.5	(20)
3	7.4	4.7	0.6	0.0	0.0	0.2	0.5	0.8	14.2	(0)*
4	10.3	8.9	7.6	0.0	6.2	0.7	1.2	2.1	37.0	(0)*
5	51.6	46.5	0.0	0.0	0.0	1.9	3.7	6.4	110.1	(1)
6	23.1	16.5	0.0	0.0	0.0	0.8	1.5	2.5	44.4	(0)*
7	29.9	24.3	0.0	0.0	0.0	1.1	2.0	3.5	60.8	(1)
8	403.0	322.6	0.0	0.0	0.0	14.6	27.7	47.2	815.1	(7)
9	9.6	5.9	0.9	0.1	0.0	0.3	0.6	0.9	18.3	(0)*
10	260.0	192.5	0.0	0.0	0.0	8.8	16.7	28.6	506.6	(4)
11	290.7	193.5	590.7	0.0	0.0	20.4	38.8	66.3	1,200.4	(10)
12	237.9	156.1	13.0	0.0	0.0	7.1	13.3	23.0	450.4	(4)
13	57.0	43.7	0.0	0.0	0.0	1.9	3.7	6.3	112.6	(1)
14	0.0	0.0	2.8	0.0	0.0	0.1	0.1	0.2	3.2	(0)*
15	0.0	0.0	101.7	0.0	2,045.4	157.1	36.5	62.5	2,403.2	(20)
16	1,406.2	823.8	31.6	0.0	115.7	40.2	67.9	116.0	2,601.4	(22)
Sub-total	$3,592.7	$2,378.5	$2,645.2	$33.6	$2,172.4	$298.6	$297.8	$507.4	$11,926.2	(100)
Percent of Total	(30)	(20)	(22)	(0)*	(18)	(3)	(3)	(4)	(100)	
					HANCOCK CREEK					
1A	$ 48.5	66.1	0.0	0.0	0.0	2.3	3.5	7.4	127.8	(7)
1B	92.5	83.7	1.8	0.0	0.0	3.6	6.7	11.5	199.8	(10)
2A	0.0	0.0	43.1	0.0	0.0	0.6	1.0	1.9	46.6	(2)
2B	180.2	121.7	149.5	10.0	0.0	8.4	15.9	27.2	512.9	(27)
3	176.8	148.8	7.3	0.0	0.0	6.6	12.6	21.5	373.6	(20)
4	273.1	163.0	3.8	0.0	0.0	11.2	14.4	24.8	490.3	(25)
5	98.8	59.8	1.0	0.0	0.0	3.0	5.8	10.0	178.4	(9)
Sub-total	$ 869.9	$ 643.1	$ 206.5	$10.0	$ 0.0	$ 35.7	$ 59.9	$104.3	$1,929.4	(100)
Percent of Total	(45)	(33)	(11)	(0)*	(0)*	(2)	(3)	(6)	(100)	
Total	$4,462.6	$3,021.6	$2,851.7	$43.6	$2,172.4	$334.3	$357.7	$611.7	$13,855.6	
Percent of Total	(32)	(22)	(21)	(0)*	(16)	(2)	(3)	(4)	(100)	

* Less than 1 percent.

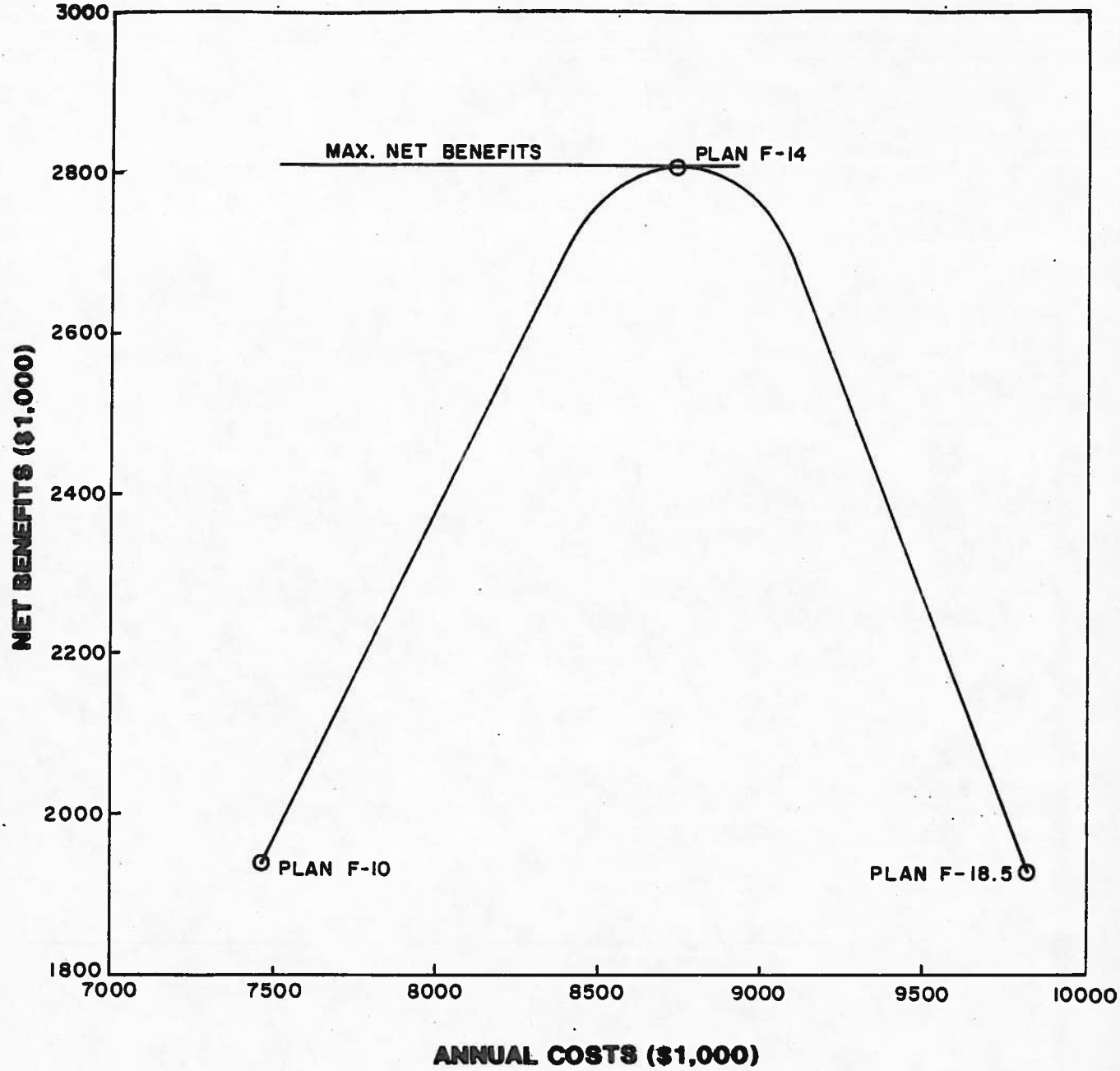
TABLE E-8
STRUCTURAL PLANS INVESTIGATED

Plan*	Limits	Description
	CHANNEL PLANS	
Minimum	From Colorado River to MOPAC RR	20-foot to 90-foot bottom width channel with two 11-foot conduits under Hwy 183
Intermediate	From Colorado River to MOPAC RR	35-foot to 90-foot bottom width channel with two 11-foot conduits under Hwy 183
Maximum	From Colorado River to MOPAC RR	45-foot to 90-foot bottom width channel with two 11-foot conduits under Hwy 183
	COMBINATION PLANS	
A14, A18.5 and A23	From Northwest Park to MOPAC RR	35-foot to 50-foot bottom width channel with two 11-foot conduits under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek
B18.5	From 45th Street to MOPAC RR	35-foot to 50-foot bottom width channel with two 11-foot conduits under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek; a tunnel diversion from 45th Street to Huck's Slough

* Plan designation are as shown in the main report. The number following the plan designation refers to the diameter of the tunnel diversion.

TABLE E-8 (continued)

Plan*	Limits	Description
C10, C18.5, C23	From 45th Street to MOPAC RR, and to North Loop Blvd on Hancock	35-foot to 50-foot bottom width channel with two 11-foot conduits under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek; a tunnel diversion from North Loop Blvd on Hancock Creek with a second intake at 45th Street to Huck's Slough
D14, D18.5	From 24th Street to MOPAC RR	35-foot to 50-foot bottom width channel with two 11-foot conduit under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek; a tunnel diversion from 24th Street to Town Lake near West Lynn Street
E14, E18.5	From 19th Street to MOPAC RR	35-foot to 50-foot bottom width channel with two 11-foot conduit under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek; a tunnel diversion from 19th Street to Town Lake near Pressler Street
F10, F14, F18.5	From 24th Street to MOPAC RR and to Houston Street on Hancock Creek	35-foot to 50-foot bottom width channel with two 11-foot conduit under Hwy 183; a tunnel diversion from Northwest Park to Lake Austin near Bull Creek; a tunnel diversion from 19th Street to Town Lake near Pressler St; a 40-foot to 50-foot bottom width concrete channel on Hancock Creek with a 10 by 10 box culvert under the shopping center



NOTE: NET BENEFITS INCLUDE INUNDATION REDUCTION BENEFITS ONLY.

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

SHOAL CREEK
AUSTIN, TEXAS

OPTIMIZATION CURVE

FIGURE E-2

The NED Plan is the 14-foot Combination Channel/Tunnel Plan designated as plan F14 and consists of the following improvements on Shoal Creek and Hancock Creek;

o a 14-foot diameter diversion tunnel, with an intake on Shoal Creek at Northwest Park downstream of Greenlawn Parkway, which empties into Lake Austin near Bull Creek;

o an 7,600-foot grass-lined channel upstream of the tunnel intake from just downstream of Foster Lane to Highway 183;

o a 1,200-foot channel improvement upstream of Highway 183 to the downstream side of the MOPAC Railroad bridge;

o two 11-foot conduits under Highway 183 on Shoal Creek;

o a 14-foot diameter diversion tunnel, with an intake on Shoal Creek near 19th Street (MLK Boulevard), which has an outfall near Town Lake by Pressler Street;

o approximately 750 feet of grass-lined channel improvement from the 19th Street tunnel outlet to Town Lake;

o a 3,200-foot improved channel on Hancock Creek from just upstream of Houston Street which goes under the shopping center and ends just downstream of Hancock Drive.

Residual Damages

Varying degrees of residual damages are expected to occur with the level of protection afforded by the project. These damages would result from floods exceeding the design level of the recommended plan and from uncontrolled drainage areas. As a rule, the residual flood losses would be greatest to low lying properties immediately adjacent to the creek. Estimated residual flood losses total $2,295,200 and represent about 17 percent of the existing flood losses. Reaches 1, 2, 8, and 16 of Shoal Creek and reaches 2, 4 and 5 of Hancock Creek are expected to experience over $150,000 each in residual damages accounting for approximately $1,785,300 or 78 percent of the total residual damages. Table E-9 shows the annual damages that could be expected to occur with the plan in operation. Table E-10 shows residual damages by reach and type.

Existing Inundation Reduction Benefits

Average annual benefits were determined by subtracting residual flood losses from the without project annual flood losses. Since future hydraulics are not expected to change, benefits to existing development are expected to remain constant over time. Reaches 1, 2, 8, 10, 11, 12, 15, and 16 of Shoal Creek have the greatest amount of benefits with $10,125,500 or about 93 percent of the total, while reaches 2B, 3, and 4 of Hancock Creek have the greatest amount with $1,090,100 or about 92 percent of the total. Combined, these seven reaches account for about $11,215,600 or about 97 percent of the project benefits which total

$11,561,100. Table E-9 displays a summary of the existing flood reduction benefits for the NED Plan, by reach. Table E-10 shows the number of structures by reach and type for various frequency floods for both with and without project conditions. Table E-11 provides the cumulative number and type of structures which receive damages by flood zone event under existing and modified conditions.

Future Flood Damages, Residuals, and Benefits

It is anticipated that future hydrologic conditions in the study area will remain unchanged since the watershed is 100 percent urbanized. Accordingly, further consideration was not given to possible hydrologic changes in the future. Specific future damage and benefit categories addressed in subsequent paragraphs are as follows:

o **Future Urban Development.** Consideration was given to potential future residential and commercial development in the flood plain. Since the study area is presently almost completely developed, it was assumed that little development would occur in the future. While there is no anticipated new future growth in the flood plain, the lower part of the Shoal Creek project is very desirable for renovation. The area contains numerous older homes and buildings, some of which have historical significance. The likelihood of any major shifts is minimal. Accordingly, potential benefits to future urban development were not quantified.

TABLE E-9
EXISTING AVERAGE ANNUAL DAMAGES, RESIDUAL DAMAGES AND BENEFITS
(February 1991 Prices and Level of Development)

Reach	Annual Damages	Residual Damages	Annual Benefits
	(in thousands of dollars)		
	SHOAL CREEK		
1	$ 1,123.0	$ 279.3	$ 843.7
2	2,425.5	366.7	2,058.8
3	14.2	14.2	0.0
4	37.0	18.7	18.3
5	110.1	65.8	44.3
6	44.4	18.9	25.5
7	60.8	26.4	34.4
8	815.1	300.4	514.9
9	18.3	8.1	10.2
10	506.6	2.6	504.0
11	1,200.4	77.3	1,123.1
12	450.4	3.2	447.2
13	112.6	1.0	111.6
14	3.2	0.0	3.2
15	2,403.2	102.6	2,300.6
16	2,601.4	268.0	2,333.4
Subtotal	11,926.2	1,553.2	10,373.0
	HANCOCK CREEK		
1A	127.8	114.4	13.4
1B	199.8	170.7	29.1
2A	46.6	1.0	45.6
2B	512.9	43.5	469.4
3	373.6	11.9	361.7
4	490.3	231.3	259.0
5	178.4	169.2	9.2
Subtotal	$ 1,929.4	$ 742.0	$ 1,187.4
TOTAL	$13,855.6	$2,295.2	$11,560.4

TABLE E-10
RESIDUAL ANNUAL DAMAGES BY REACH AND TYPE
(February 1991 prices)

Reach	Residential Structures	Residential Contents	Commercial	Public	Industrial	Transportation	Comm and Utilities	Public Health and Relief	Total	% of Total
				(thousands of dollars)						
					SHOAL CREEK					
1	$ 6.3	$ 4.6	$ 237.7	$ 0.0	$ 0.3	$ 4.9	$ 9.4	$ 16.1	$ 279.3	(9)
2	30.5	17.1	269.2	9.5	0.1	6.4	12.7	21.2	366.7	(20)
3	7.4	4.7	0.6	0.0	0.0	0.2	0.5	0.8	14.2	(0)*
4	5.2	4.4	3.4	0.0	3.7	0.3	0.7	1.0	18.7	(0)*
5	30.4	28.6	0.0	0.0	0.0	1.0	2.0	3.8	65.8	(1)
6	9.8	7.1	0.0	0.0	0.0	0.3	0.7	1.0	18.9	(0)*
7	13.3	10.2	0.0	0.0	0.0	0.4	0.9	1.6	26.4	(1)
8	150.7	116.7	0.0	0.0	0.0	5.4	10.2	17.4	300.4	(7)
9	3.7	2.8	0.7	0.1	0.0	0.1	0.2	0.5	8.1	(0)*
10	1.6	0.8	0.0	0.0	0.0	0.0	0.1	0.1	2.6	(4)
11	17.0	12.9	39.0	0.0	0.0	1.3	2.6	4.5	77.3	(10)
12	1.8	1.0	0.0	0.0	0.0	0.1	0.1	0.2	3.2	(4)
13	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.1	1.0	(1)
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0)*
15	0.0	0.0	2.4	0.0	85.5	5.6	3.4	5.7	102.6	(20)
16	123.4	112.4	0.1	0.0	2.5	4.9	9.1	15.6	268.0	(22)
Sub-total	$401.8	$323.5	$553.1	$9.6	$92.1	$30.9	$52.6	$89.6	$1,553.2	(100)
Percent of Total	(26)	(21)	(36)	(0)*	(6)	(2)	(3)	(6)	(100)	
					HANCOCK CREEK					
1A	$ 46.8	55.9	0.0	0.0	0.0	2.0	3.1	6.6	114.4	(7)
1B	79.4	71.5	1.0	0.0	0.0	3.0	5.8	10.0	170.7	(10)
2A	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	(2)
2B	13.2	11.4	13.3	0.8	0.0	0.8	1.5	2.5	43.5	(27)
3	5.9	4.7	0.2	0.0	0.0	0.2	0.2	0.7	11.9	(20)
4	118.3	83.4	2.6	0.0	0.0	6.0	7.7	13.3	231.3	(25)
5	91.1	58.7	1.0	0.0	0.0	3.0	5.7	9.7	169.2	(9)
Sub-total	$ 354.7	$ 285.6	$ 19.1	$ 0.8	$ 0.0	$ 15.0	$ 24.0	$ 42.8	$ 742.0	(100)
Percent of Total	(45)	(33)	(11)	(0)*	(0)*	(2)	(3)	(6)	(100)	
Total	$ 756.5	$ 609.1	$ 572.2	$10.4	$ 92.1	$ 45.9	$ 76.6	$132.4	$2,295.2	
Percent of Total	(33)	(27)	(25)	(0)*	(4)	(2)	(3)	(6)	(100)	

* Less than 1 percent.

TABLE E-11
CUMULATIVE NUMBER OF STRUCTURES DAMAGED BY FLOOD EVENT ZONE UNDER EXISTING AND MODIFIED CONDITIONS

Flood Zone (years)	Single-Family Residential		Multi-Family Residential		Commercial		Industrial		Public		Transportation/ Communication/ Utilities		Total Structures Damaged	
	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified
Reach 1														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	7	0	0	0	13	0	0	0	0	0	0	0	20	0
5-10	9	1	0	0	22	0	0	0	0	0	0	0	31	1
10-25	9	7	0	0	27	17	2	0	0	0	0	0	38	24
25-50	9	9	0	0	32	26	2	0	0	0	0	0	43	35
50-100	10	9	2	0	32	27	2	0	0	0	1	0	47	36
100-500	10	10	3	2	36	32	2	2	0	0	1	0	52	46
500-SPF	10	10	3	3	38	36	2	2	0	0	1	1	54	52
Reach 2														
0-2	1	0	0	0	11	0	0	0	0	0	0	0	12	0
2-5	4	0	0	0	19	0	0	0	1	0	0	0	24	0
5-10	9	1	1	0	24	19	0	0	2	1	1	0	37	21
10-25	10	7	1	0	29	20	0	0	2	1	1	0	43	28
25-50	10	9	1	1	35	24	1	0	4	2	2	1	53	37
50-100	15	10	1	1	38	29	1	0	5	2	2	1	62	43
100-500	16	15	1	1	41	38	1	1	5	5	2	2	66	62
500-SPF	17	16	1	1	42	41	1	1	5	5	2	2	68	66
Reach 3														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-25	1	0	0	0	0	0	0	0	0	0	0	0	1	0
25-50	1	1	0	0	0	0	0	0	0	0	0	0	1	1
50-100	3	2	1	1	0	0	0	0	0	0	1	1	5	4
100-500	3	3	1	1	2	2	0	0	0	0	1	1	7	7
500-SPF	3	3	1	1	3	3	0	0	0	0	1	1	8	8
Reach 4														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-25	5	3	0	0	0	0	1	1	0	0	0	0	6	4
25-50	8	5	0	0	1	0	1	1	0	0	0	0	10	6
50-100	16	8	0	0	2	1	1	1	0	0	0	0	19	10
100-500	18	16	0	0	3	2	1	1	0	0	0	0	22	19
500-SPF	20	19	0	0	3	3	1	1	0	0	0	0	24	23
Reach 5														
0-2	3	0	0	0	0	0	0	0	0	0	0	0	3	0
2-5	3	0	0	0	0	0	0	0	0	0	0	0	3	0
5-10	3	3	0	0	0	0	0	0	0	0	0	0	3	3
10-25	3	3	0	0	0	0	0	0	0	0	0	0	3	3
25-50	4	3	0	0	0	0	0	0	0	0	0	0	4	3
50-100	5	3	0	0	0	0	0	0	0	0	0	0	5	3
100-500	15	5	0	0	0	0	0	0	0	0	0	0	15	5
500-SPF	20	10	0	0	0	0	0	0	0	0	0	0	20	10
Reach 6														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	1	0	0	0	0	0	0	0	0	0	0	0	1	0
5-10	5	5	0	0	0	0	0	0	0	0	0	0	5	0
10-25	7	5	0	0	0	0	0	0	0	0	0	0	7	5
25-50	9	5	0	0	0	0	0	0	0	0	0	0	9	5
50-100	10	7	0	0	0	0	0	0	0	0	0	0	10	5
100-500	10	10	0	0	0	0	0	0	0	0	0	0	10	7
500-SPF	12	10	0	0	0	0	0	0	0	0	0	0	12	10

TABLE E-11 (Continued)
CUMULATIVE NUMBER OF STRUCTURES DAMAGED
BY FLOOD EVENT ZONE
UNDER EXISTING AND MODIFIED CONDITIONS

Flood Zone (years)	Single-Family Residential		Multi-Family Residential		Commercial		Industrial		Public		Transportation/ Communication/ Utilities		Total Structures Damaged	
	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified
Reach 7														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	7	1	0	0	0	0	0	0	0	0	0	0	0	0
5-10	7	1	0	0	0	0	0	0	0	0	0	0	7	1
10-25	11	9	0	0	0	0	0	0	0	0	0	0	7	1
25-50	17	11	0	0	0	0	0	0	0	0	0	0	11	9
50-100	20	17	0	0	0	0	0	0	0	0	0	0	17	11
100-500	24	20	0	0	0	0	0	0	0	0	0	0	20	17
500-SPF	30	24	0	0	0	0	0	0	0	0	0	0	24	20
Reach 8														
0-2	15	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	20	15	0	0	0	0	0	0	0	0	0	0	15	0
5-10	48	25	0	0	0	0	0	0	0	0	0	0	20	0
10-25	50	25	0	0	0	0	0	0	0	0	0	0	48	15
25-50	70	48	0	0	0	0	0	0	0	0	0	0	50	25
50-100	80	58	0	0	0	0	0	0	0	0	0	0	70	25
100-500	80	80	0	0	0	0	0	0	0	0	0	0	80	48
500-SPF	101	90	0	0	0	0	0	0	0	0	0	0	80	58
Reach 9														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-50	0	0	0	0	0	0	0	0	1	1	0	0	1	1
50-100	2	2	0	0	3	0	0	0	1	1	0	0	6	3
100-500	43	18	0	0	3	3	0	0	1	1	0	0	47	22
500-SPF	57	43	0	0	3	3	0	0	1	1	0	0	61	47
Reach 10														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	17	0	1	0	0	0	0	0	0	0	0	0	18	0
5-10	53	0	1	0	0	0	0	0	0	0	0	0	54	0
10-25	77	0	2	0	0	0	0	0	0	0	0	0	79	0
25-50	77	0	2	0	0	0	0	0	0	0	0	0	79	0
50-100	87	1	15	0	0	0	0	0	0	0	0	0	102	0
100-500	96	17	31	0	0	0	0	0	0	0	0	0	127	1
500-SPF	122	53	36	1	1	0	0	0	0	0	0	0	159	18
Reach 11														
0-2	0	0	0	0	6	0	0	0	0	0	0	0	6	0
2-5	0	0	0	0	10	3	0	0	0	0	0	0	10	3
5-10	0	0	0	0	15	6	0	0	0	0	0	0	15	6
10-25	0	0	0	0	21	6	0	0	0	0	0	0	21	6
25-50	0	0	0	0	21	10	0	0	0	0	0	0	21	10
50-100	0	0	0	0	21	10	0	0	0	0	0	0	21	10
100-500	0	0	0	0	27	10	0	0	0	0	0	0	27	10
500-SPF	0	0	0	0	27	10	0	0	0	0	0	0	27	10
Reach 12														
0-2	4	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	22	0	0	0	2	0	0	0	0	0	0	0	6	0
5-10	44	0	0	0	4	0	0	0	0	0	0	0	26	0
10-25	60	0	0	0	4	0	0	0	0	0	0	0	48	0
25-50	75	0	0	0	5	0	0	0	0	0	0	0	65	0
50-100	100	4	0	0	7	0	0	0	0	0	0	0	82	0
100-500	108	14	0	0	8	4	0	0	0	0	0	0	108	4
500-SPF	108	14	0	0	8	4	0	0	0	0	0	0	116	8

TABLE E-11 (Continued)
CUMULATIVE NUMBER OF STRUCTURES DAMAGED
BY FLOOD EVENT ZONE
UNDER EXISTING AND MODIFIED CONDITIONS

Flood Zone (years)	Single-Family Residential		Multi-Family Residential		Commercial		Industrial		Public		Transportation/ Communication/ Utilities		Total Structures Damaged	
	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified
Reach 13														
0-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	6	0	0	0	0	0	0	0	0	0	0	0	2	0
5-10	6	0	0	0	0	0	0	0	0	0	0	0	6	0
10-25	10	0	0	0	0	0	0	0	0	0	0	0	6	0
25-50	16	0	0	0	0	0	0	0	0	0	0	0	10	0
50-100	21	2	0	0	0	0	0	0	0	0	0	0	16	0
100-500	27	2	0	0	0	0	0	0	0	0	0	0	21	0
500-SPF	32	2	0	0	0	0	0	0	0	0	0	0	27	2
Reach 14														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50-100	0	0	0	0	1	0	0	0	0	0	0	0	1	0
100-500	0	0	0	0	2	0	0	0	0	0	0	0	2	0
500-SPF	0	0	0	0	2	0	0	0	0	0	0	0	2	0
Reach 15														
0-2	0	0	0	0	0	0	3	0	0	0	0	0	3	0
2-5	0	0	0	0	0	0	3	2	0	0	0	0	3	2
5-10	0	0	0	0	1	0	3	3	0	0	0	0	4	3
10-25	0	0	0	0	1	0	3	3	0	0	0	0	4	3
25-50	0	0	0	0	1	0	3	3	0	0	0	0	4	3
50-100	0	0	0	0	1	1	3	3	0	0	0	0	4	4
100-500	0	0	0	0	1	1	3	3	0	0	0	0	4	4
500-SPF	0	0	0	0	1	1	3	3	0	0	0	0	4	4
Reach 16														
0-2	0	0	1	0	0	0	0	0	0	0	1	0	2	0
2-5	0	0	3	1	1	0	1	0	0	0	1	0	6	1
5-10	0	0	4	1	1	0	1	0	0	0	1	0	7	1
10-25	0	0	4	1	1	0	2	0	0	0	1	1	8	2
25-50	0	0	4	1	1	0	3	0	0	0	1	1	9	2
50-100	0	0	4	3	6	1	4	1	0	0	1	1	15	6
100-500	0	0	4	4	6	6	4	4	0	0	1	1	15	15
500-SPF	0	0	4	4	6	6	4	4	0	0	1	1	15	15
SHOAL TOTAL														
0-2	25	0	1	0	17	0	3	0	0	0	1	0	22	0
2-5	80	16	4	1	32	3	4	2	1	0	1	0	67	6
5-10	175	35	6	1	45	25	4	3	2	1	2	0	139	30
10-25	234	52	7	1	56	26	6	4	2	1	2	1	248	49
25-50	287	82	7	2	64	34	8	4	5	3	3	2	321	80
50-100	359	114	21	5	79	42	9	5	6	3	4	3	406	110
100-500	440	200	37	6	93	66	9	9	6	6	4	4	508	173
500-SPF	522	284	42	7	96	71	9	9	6	6	4	4	597	211

TABLE E-11 (Continued)
CUMULATIVE NUMBER OF STRUCTURES DAMAGED
BY FLOOD EVENT ZONE
UNDER EXISTING AND MODIFIED CONDITIONS

Flood Zone (years)	Single-Family Residential		Multi-Family Residential		Commercial		Industrial		Public		Transportation/ Communication/ Utilities		Total Structures Damaged	
	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified
HANCOCK CREEK														
Reach 1A														
0-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	2	0	0	0	0	0	0	0	0	0	0	0	1	0
5-10	5	5	0	0	0	0	0	0	0	0	0	0	2	0
10-25	8	8	0	0	0	0	0	0	0	0	0	0	5	0
25-50	9	9	0	0	0	0	0	0	0	0	0	0	8	5
50-100	9	9	0	0	0	0	0	0	0	0	0	0	9	8
100-500	15	15	0	0	0	0	0	0	0	0	0	0	9	9
500-SPF	15	15	0	0	0	0	0	0	0	0	0	0	15	9
Reach 1B														
0-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	2	0	0	0	0	0	0	0	0	0	0	0	1	0
5-10	5	5	0	0	0	0	0	0	0	0	0	0	2	0
10-25	8	8	0	0	0	0	0	0	0	0	0	0	5	0
25-50	9	9	0	0	0	0	0	0	0	0	0	0	8	5
50-100	9	9	0	0	0	0	0	0	0	0	0	0	9	8
100-500	15	15	0	0	0	0	0	0	0	0	0	0	9	9
500-SPF	15	15	0	0	0	0	0	0	0	0	0	0	15	9
Reach 2A														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	5	0	0	0	0	0	5	0
5-10	0	0	0	0	0	0	5	0	0	0	0	0	5	0
10-25	0	0	0	0	0	0	6	0	0	0	0	0	6	0
25-50	0	0	0	0	0	0	6	0	0	0	0	0	6	0
50-100	0	0	0	0	0	0	6	4	0	0	0	0	6	4
100-500	0	0	0	0	0	0	6	5	0	0	0	0	6	5
500-SPF	0	0	0	0	0	0	6	5	0	0	0	0	6	5
Reach 2B														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	0	0	0	0	1	0	0	0	0	0	1	0
5-10	2	0	0	0	0	0	11	0	0	0	0	0	11	0
10-25	2	0	0	0	0	0	11	0	0	0	0	0	13	0
25-50	2	2	0	0	0	0	11	1	0	0	0	0	13	1
50-100	2	2	0	0	0	0	11	11	0	0	0	0	13	11
100-500	2	2	0	0	0	0	16	11	0	0	0	0	18	13
500-SPF	2	2	0	0	0	0	17	16	1	1	0	0	20	19
Reach 3														
0-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-5	0	0	5	0	0	0	0	0	0	0	0	0	5	0
5-10	0	0	6	0	0	0	0	0	0	0	1	0	7	0
10-25	5	0	9	0	2	0	0	0	0	0	1	0	12	0
25-50	5	0	9	0	2	0	0	0	0	0	1	0	17	0
50-100	11	0	12	5	3	0	0	0	0	0	1	0	21	5
100-500	13	0	14	6	3	2	0	0	0	0	1	0	29	8
500-SPF	13	11	14	14	8	3	0	0	0	0	1	1	36	18

TABLE E-11 (Continued)
CUMULATIVE NUMBER OF STRUCTURES DAMAGED
BY FLOOD EVENT ZONE
UNDER EXISTING AND MODIFIED CONDITIONS

Flood Zone (years)	Single-Family Residential		Multi-Family Residential		Commercial		Industrial		Public		Transportation/ Communication/ Utilities		Total Structures Damaged	
	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified	Exist	Modified
Reach 4														
0-2	22	0	2	0	0	0	0	0	0	0	0	0	2	0
2-5	57	0	3	0	0	0	0	0	0	0	0	0	25	0
5-10	75	22	4	4	2	0	0	0	0	0	3	0	66	4
10-25	92	40	6	4	2	0	0	0	0	0	4	0	87	4
25-50	92	57	8	4	2	2	0	0	0	0	4	3	106	31
50-100	106	92	8	8	3	2	0	0	0	0	6	4	109	54
100-500	120	106	8	8	4	3	0	0	0	0	7	6	125	74
500-SPF	120	120	8	8	4	4	0	0	0	0	7	7	139	111
Reach 5														
0-2	7	7	0	0	0	0	0	0	0	0	0	0	0	0
2-5	11	11	0	0	0	0	0	0	0	0	0	0	7	0
5-10	30	30	0	0	2	2	0	0	0	0	0	0	13	9
10-25	30	30	0	0	2	2	0	0	0	0	0	0	32	13
25-50	30	30	0	0	2	2	0	0	0	0	0	0	32	32
50-100	84	84	0	0	2	2	0	0	0	0	0	0	32	32
100-500	84	84	0	0	2	2	0	0	0	0	0	0	86	32
500-SPF	84	84	0	0	2	2	0	0	0	0	0	0	86	86
HANCOCK TOTAL														
0-2	31	7	2	0	0	0	0	0	0	0	0	0	2	0
2-5	72	11	8	0	0	0	6	0	0	0	0	0	45	0
5-10	117	62	10	4	4	2	16	0	0	0	4	0	106	13
10-25	145	86	15	4	6	2	17	0	0	0	5	0	160	17
25-50	147	107	17	4	6	4	17	1	0	0	5	3	190	74
50-100	221	196	20	13	8	4	17	15	0	0	7	4	199	122
100-500	249	222	22	14	9	7	22	16	0	0	8	6	282	150
500-SPF	249	247	22	22	14	9	23	21	1	1	8	8	317	257
GRAND TOTAL														
0-2	56	7	3	0	17	0	3	0	0	0	1	0	24	0
2-5	152	27	12	1	32	3	10	2	1	0	1	0	112	6
5-10	292	97	16	5	49	27	20	3	2	1	6	0	245	43
10-25	379	138	22	5	62	28	23	4	2	1	7	1	408	66
25-50	434	189	24	6	70	38	25	5	5	3	8	5	511	154
50-100	580	310	41	18	87	46	26	20	6	3	11	7	605	232
100-500	689	422	59	20	102	73	31	25	6	6	12	10	790	323
500-SPF	771	531	64	29	110	80	32	30	7	7	12	12	914	468

Other Inundation Reduction Benefits

In addition, consideration was given to other potential types of flood control benefits which would accrue to the NED Plan. Two additional benefit categories identified and added to the benefits claimed are vehicular damage reduction and insurance overhead cost reduction benefits. A brief description of the calculations performed and the resultant benefits for these two categories are presented below.

Vehicular Damage Reduction. The average annual benefits derived from the reduction of flood damages to vehicles are estimated to total $236,100 on Shoal Creek and $39,300 on Hancock Creek. Based on data collected during the initiation of this study and from recent flood studies by the Galveston and Fort Worth districts a damage factor for the area was derived considering the average number of vehicles per household, an estimated value, actual damages incurred historically, and the probability of the vehicles actual presence during the flood. Data collected indicated, a damage estimate factor of 0.045 was derived for Shoal and Hancock Creeks. The factor was multiplied by the average annual damages of residential structures to determine total vehicle damages. Shoal and Hancock Creek vehicle damages were derived as follows:

Shoal Creek
- Existing Conditions:
  - $5,971,200 (residential damages) X 0.045 = $268,700
- Improved Conditions:
  - $ 725,300 (residential damages) X 0.045 = $ 32,600

Hancock Creek
- Existing Conditions:
  - $1,513,000 (residential damages) X 0.045 = 68,100
- Improved Conditions:
  - $ 640,300 (residential damages) X .045 = 28,800

A summary of existing and residual average annual vehicular damages and the resulting benefits is presented in table E-12.

TABLE E-12

ESTIMATED ANNUAL VEHICULAR DAMAGES AND BENEFITS
(February 1991 prices and development)

Location	Annual Damages Without Project	Annual Damages With Project	Annual Benefits
Shoal Creek	$268,700	$ 32,600	$236,100
Hancock Creek	68,100	28,800	39,300
Total	$336,800	$ 61,400	$275,400

Insurance Overhead Cost Reduction. The city of Austin is under the regular Flood Insurance Program as directed by the National Flood Insurance Administration. Currently, under this program, the annual overhead or administrative cost is $79 per policy, as per Economic Guidance Memorandum Number 90-2 for fiscal year 1991. The total cost can be derived by multiplying the overhead expense by the number of insured structures in the 100-year flood plain. Annual benefits can be determined by subtracting the administrative cost of flood insurance policies for homes remaining in the 100-year flood plain. A total of 783 homes were found within the 100 year flood plain, with 509 along Shoal Creek and 279 along Hancock Creek for the NED Plan. An annual overhead cost of $79 per policy yields expenses of $40,200 and $21,700 on Shoal and Hancock Creeks respectively, a total cost of $61,900. Under the recommended plan the number of homes along Shoal and Hancock Creeks within the 100 year flood plain will be reduced to 135 and 236, respectively. The total annual overhead cost under the NED Plan is reduced a total of 53 percent to $29,300; $10,700 for Shoal Creek, a 74 percent decrease, and $18,600 for Hancock Creek, a 14 percent reduction. Using this procedure, the annual insurance overhead reduction benefits are computed as $29,500 for Shoal Creek and $3,000 for Hancock Creek, for a total of $32,500 annually. A detailed computation of these benefits is shown in table E-13.

Recreation Benefits

According to 1985 TORP facility standards, a 1.4-mile trail can accommodate about 18,900 visitors per mile each year along the 1.4-mile trail each year. The benefits accruing to this visitation were estimated in accordance with Appendix A of ER 1105-2-240, Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. Under the guidelines for assigning general recreation point values, a recreation planner assigned a total of 23 points for the proposed plan. The negative and positive attributes of the trail were taken into consideration and assigned a value accordingly. The trail will provide two general activities common to the site, 2 points; one of several activity areas within a 30 minute travel time, 1 point; adequate facilities to conduct the activities, 7 points; fair access and good roads, 8 points; average aesthetic qualities, 5 points. The range of approved unit day values for FY 90 (Economic Guidance Memo #90-2) for general recreation is $2.75 for 20 points and $3.20 for 30 points. The 45 cent difference allows 4.5 cents per point. Therefore, 23 points converts to $2.90 per visitor day. A benefit value of $2.90 multiplied by 26,460 visitor-days will yield benefits of approximately $76,900 per year.

Benefit Summary

The benefits attributable to the NED Plan were calculated based on a 100-year project life (1996-2096) and a 8-3/4 percent interest rate. Estimates of the project benefits which would accrue to this plan are presented in table E-14.

TABLE E-13

ESTIMATED ANNUAL INSURANCE OVERHEAD REDUCTION BENEFITS
(February 1991 prices and development)

Location/Reach	Without Project		With Project		Annual Benefits
	No.	Cost	No.	Cost	
Shoal Creek					
1	10	$ 790	7	$ 553	$ 237
2	15	1,185	6	474	711
3	3	237	0	0	237
4	17	1,343	0	0	1,343
5	8	632	3	237	395
5	10	790	6	474	316
7	24	1,896	9	711	1,185
8	93	7,347	48	3,792	3,555
9	19	1,501	0	0	1,501
10	131	10,349	20	1,580	8,769
11	49	3,871	19	1,501	2,370
12	98	7,742	14	1,106	6,636
13	31	2,449	3	237	2,212
14	0	0	0	0	0
15	0	0	0	0	0
16	1	79	0	0	79
Total	509	$40,200	135	$10,700	$29,500
Hancock Creek					
1A	12	948	0	0	948
1B	30	2,370	8	632	1,738
2A	0	0	0	0	0
2B	0	0	0	0	0
3	11	869	7	553	316
4	127	10,033	127	10,033	0
5	94	7,426	94	7,426	0
Subtotal	274	$21,600	236	$18,600	$ 3,000
Combined Total	783	$61,800	371	$29,300	$32,500

TABLE E-14

SUMMARY OF AVERAGE ANNUAL BENEFITS
NED PLAN
(February 1991 prices, 8-3/4% interest rate)

Category	Benefits
Inundation reduction	$11,560,400
Vehicular damage reduction	275,400
Insurance overhead reduction	32,500
Recreation	76,900
Total	$11,945,200

Intangible Benefits

It is anticipated that certain intangible benefits would be realized from the project's construction. The intangible benefits would take the form of:

o Reduction in the hazard to life from the occurrence of floods;

o Reduction in the possibility of epidemics caused by flood damage to sewer and water systems;

o Prevention of interruptions to normal community, business, and social activities; and

o The decreased cost of operation of public services.

No attempt was made to evaluate potential benefits for these activities due to difficulty in quantifying such losses.

BENEFIT-TO-COST ANALYSIS

The normal measure of economic feasibility is the benefit-to-cost ratio being greater than or equal to 1.0. Table E-15 shows an economic summary of the NED Plan and the benefit-to-cost ratio.

TABLE E-15

ECONOMIC SUMMARY
NED PLAN
(February 1991 prices, 8-3/4 percent interest)

	First Cost	Average Annual Charges	Average Annual Benefits	Benefit-to-Cost Ratio	Net Benefits
Flood Control	$82,050,000	$8,738,000	$11,868,300	1.4	$3,130,300
Recreation	222,000	30,000	76,900	2.6	46,900
Total	$82,272,000	$8,768,000	$11,945,200	1.4	$3,177,200

INCREMENTAL JUSTIFICATION OF THE RECOMMENDED PLAN

To further evaluate the optimization of the Recommended Plan, an incremental analysis of the various components of the plan was performed. The areas identified for this analysis were: the tunnel at Northwest Park, the channelization from the MOPAC Railroad to Foster Lane, the tunnel at 19th Street, and the channel on Hancock Creek. This, last added, incremental analysis is summarized in table E-16.

UPDATING BENEFIT-TO-COST RATIOS

Various project planning, authorization, and funding procedures have been instituted to reduce the necessity of updating benefit-to-cost ratios to current levels. However, a current analysis of project benefits will be required at the initiation of construction, particularly when more than four years has passed since the completion of the last evaluation.

To update the current estimates of project benefits, a representative sample from each of the various property types in each reach should be taken to verify the structure and content values. In addition, any significant changes in the cost and number of vehicles per household, and insurance overhead costs should be accounted for as well. Future recalculation of the benefit-to-cost ratio utilizing this sample data will provide an indication of the current level of flood control benefits.

TABLE E-16

INCREMENTAL ANALYSIS, NED PLAN
(February 1991 prices, 8-3/4 percent interest)

Increment	Total First Cost	Total Investment[1]	Average Annual Cost	Average Annual Benefits[2]	Benefit-to-Cost Ratio	Net Benefits
Northwest Park tunnel	$41,773,000	$47,499,000	$4,170,000	$ 5,168,000	1.2	$ 998,000
Northwest Park tunnel and channelization to Foster Lane	51,605,000	58,678,000	5,154,000	7,940,000	1.5	2,786,000
Incremental analysis	9,832,000	11,179,000	984,000	2,772,000	2.8	1,788,000
Northwest Park tunnel, channelization to Foster Lane and tunnel at 19th Street	75,062,000	85,350,000	7,494,000	10,373,000	1.4	2,879,000
Incremental analysis	23,457,000	26,672,000	2,340,000	2,433,000	1.0	93,000
Northwest Park tunnel, channelization to Foster Lane, tunnel at 19th Street, and channel on Hancock (NED plan)	81,697,000	97,074,000	8,525,000	11,560,000	1.4	3,035,000
Incremental analysis	$ 6,635,000	11,724,000	$ 611,000	$ 1,187,000	1.9	576,000

[1] Total Investment includes interest during construction.
[2] Average annual benefits include only inundation reduction benefits.

LAST ADDED INCREMENTAL ANALYSIS, NED PLAN
(February 1991 prices, 8-3/4 percent interest)

Increment	Total First Cost	Total Investment[1]	Average Annual Cost	Average Annual Benefits[2]	Benefit-to-Cost Ratio	Net Benefits
19th Street tunnel	$23,457,000	$25,539,000	$2,245,000	$ 2,433,000	1.1	$ 188,000
19th Street tunnel and Hancock channelization	30,092,000	33,480,000	2,948,000	3,620,000	1.2	672,000
Incremental analysis	6,635,000	7,941,000	601,000	1,187,000	1.9	586,000
19th Street tunnel, Hancock channelization, Shoal channelization to Foster Lane	39,924,000	45,396,000	3,996,000	6,392,000	1.6	2,396,000
Incremental analysis	9,832,000	11,916,000	884,000	2,772,000	3.1	1,888,000
19th Street tunnel, Hancock channelization, Shoal channelization to Foster Lane, and Northwest Park tunnel (NED plan)	81,697,000	97,074,000	8,525,000	11,560,000	1.4	3,035,000
Incremental analysis	$41,773,000	51,678,000	$3,819,000	$ 5,168,000	1.4	1,349,000

[1] Total Investment includes interest during construction.
[2] Average annual benefits include only inundation reduction benefits.

EVALUATION OF THE LOCALLY PREFERRED PLAN

While Plan F14, the NED Plan, is the "best" plan from an economic standpoint, the city of Austin was presented the opportunity to review and make a decision on the recommendations. After weighing all of the data provided, the city has made the decision to implement only a portion of the NED plan. The city has indicated they would like to proceed with the Hancock Creek Channel portion of the project. Since this is known as a "buy-down" from the NED plan, the same cost sharing rules apply as long as the smaller plan is still feasible. The Corps does not object to the deviation from the NED plan, and therefore, the locally preferred plan was selected as the Recommended Plan.

RECOMMENDED PLAN

The recommended plan is the Hancock Creek channel portion of the NED plan. On Hancock Creek, 1,500 feet of concrete U-wall channel will begin just upstream of Houston Street and extend downstream to Burnet Road. A box culvert will divert some water around the shopping center and will flow back into Hancock Creek below the shopping center. The U-wall channel will continue from the shopping center to below Hancock Drive and then transition into a grass-lined channel ending about 700 feet downstream of Hancock Drive. The total length of improved channel on Hancock Creek is 3,200 feet.

PLAN ACCOMPLISHMENTS

The major benefits that will result from the plan are reduction of existing flood damages to structures along Hancock Creek. Average annual benefits of $1,187,400 are estimated for the existing improvements in the area. The plan has residual damages of $742,000. The level of protection of the plan varies throughout the length of the creek. Table E-16 provides an estimation of the level of protection of the project by reach. There are no induced damages downstream of the recommended plan.

TABLE E-17

LEVEL OF PROTECTION AND PERCENTAGE DAMAGE REDUCTION RECOMMENDED PLAN

HANCOCK CREEK

Reach	Existing Level	Modified Level	Percent Damage Reduction
1A	2	10	10
1B	1	2	15
2A	5	100	95
2B	5	50	92
3	10	100	97
4	2	5	53
5	2	2	6
Hancock Overall Range	1 to 10	2 to 100	62

COSTS

First Cost. The economic cost of the selected plan described includes estimates for lands and damages, construction, engineering and design, supervision and administration, and contingencies. Construction cost data for the channel were developed using material, equipment, and labor costs typical for work of this nature in the Austin vicinity in February 1991. Table E-18 gives the detailed first cost estimate for the selected plan.

TABLE E-18
COST ESTIMATE
RECOMMENDED PLAN
(February 1991 price level)

Cost Acct No.	Item	Amount
01	LANDS AND DAMAGES	$ 442,300
	Contingencies 25%±	110,600
	TOTAL LANDS AND DAMAGES	$ 552,900
02	RELOCATIONS	
	Roads and bridges	190,300
	Utilities	195,200
	Subtotal	$ 385,500
	Contingencies 25%±	93,700
	TOTAL RELOCATIONS	$ 479,200
09	CHANNEL	3,485,900
	Contingencies 25%±	844,700
	TOTAL CHANNEL	$ 4,330,600
18	CULTURAL RESOURCES	800
	Contingencies 25 %±	200
	TOTAL CULTURAL RESOURCES	$ 1,000
30	ENGINEERING AND DESIGN	741,000
31	SUPERVISION AND ADMINISTRATION	530,000
	TOTAL PROJECT FIRST COST	$ 6,634,700

Annual Charges. To be comparable with benefit estimates, the project first cost was converted to an equivalent average annual basis. To that, estimates of average operation and maintenance costs and annual equivalent charges for replacement of features not expected to function properly over the entire period of analysis were added. For the purpose of determining the total investment, construction was assumed to be phased and a two year construction period was assumed. Table E-19 provides a breakdown of annual charges for the Recommended Plan.

TABLE E-19

HANCOCK CREEK CHANNEL PLAN
AVERAGE ANNUAL CHARGES

Total First Cost	$ 6,634,700
Interest During Construction	589,000
Total Investment	$ 7,223,700
Interest and Amortization (50 years at 8-3/4%)	641,800
Annual operation, maintenance and replacements	5,000
Total Annual Charges	$ 646,800

BENEFITS

This section presents information on the economic evaluations performed to calculate the benefits accruing to the selected plan of improvement for Hancock Creek. The benefits assignable to this plan encompass only those that are tangible and quantifiable.

Existing Inundation Reduction Benefits. Average annual benefits were determined by subtracting residual flood losses from the without project annual flood losses. Since future hydraulics are not expected to change, benefits to existing development are expected to remain constant over time. Reaches 2B, 3, and 4 of Hancock Creek have the greatest amount with $1,090,100, or about 92 percent of the total. Table E-20 displays a summary of the existing flood reduction benefits for the Recommended Plan, by reach.

TABLE E-20

EXISTING AVERAGE ANNUAL DAMAGES, RESIDUAL DAMAGES AND BENEFITS
(February 1991 Prices and Level of Development)

Reach	Annual Damages	Residual Damages	Annual Benefits
	(in thousands of dollars)		
		HANCOCK CREEK	
1A	127.8	114.4	13.4
1B	199.8	170.7	29.1
2A	46.6	1.0	45.6
2B	512.9	43.5	469.4
3	373.6	11.9	361.7
4	490.3	231.3	259.0
5	178.4	169.2	9.2
Subtotal	$ 1,929.4	$ 742.0	$ 1,187.4

Benefit Summary. The benefits attributable to the recommended plan were calculated based on a 50-year project life (1996-2046) and an 8-3/4 percent interest rate. Subsequent to the completion of the economic analysis, consideration was given to other potential types of flood control benefits which would accrue to the recommended improvements. Two additional benefit categories identified were vehicular damage reduction and insurance cost reduction benefits. Estimates of the project benefits which would accrue to this plan are presented in table E-21.

TABLE E-21

SUMMARY OF AVERAGE ANNUAL FLOOD CONTROL BENEFITS
(February 1991 price and level of development)

Category	Benefits
Inundation Reduction	$ 1,187,400
Vehicular Damage Reduction	39,300
Insurance Overhead Reduction	3,000
Total	$ 1,229,700

ECONOMIC JUSTIFICATION

The normal measure of economic feasibility is the benefit-to-cost ratio being greater than or equal to 1.0. The average annual cost for the Recommended Plan is $646,800. Average annual benefits are estimated to be $1,229,700. This results in a benefit-to-cost ratio of 1.9 to 1.0.

RISK, UNCERTAINTY AND SENSITIVITY ANALYSIS

Many potential sources of risk and uncertainty are inherent in water resource planning. Among these are the projection of water surface profiles, the degree of accuracy of topographic maps, the range of values for depth damage curves, and the estimated value of flood plain property. Appropriate measures were taken, where possible, to reduce the degree of error associated with each of these potential sources. The degree of error in developing the existing condition hydraulics model was minimized by close coordination with the city of Austin Engineering Department under the assumption that they would have the best available information. Factors used to estimate the percentage of bridge blockage along the creek were also verified by the city. The values are not expected to change, and historically reoccur above the 25-year storm.

A sensitivity analysis was conducted to determine the outside limit for various factors which would render the project economically unfeasible. These factors include property values, first costs, and the interest rate. Appropriate precautions were taken to minimize cost and value estimate error, but they remain a source of uncertainty. Examination of structure and content values show that a reduction of over 31 percent would reduce damages and benefits proportionately and render the project economically unfeasible. The likelihood of an error of this magnitude is remote since coordination with appropriate city agencies was accomplished.

An analysis was also conducted to determine the effects of changes in the total project first cost and the prevailing interest rate. Allowing the interest rate to increase by 10 percent and 25 percent produces an increase in the annual charges and a subsequent decrease in the benefit-to-cost ratio. However, in both cases the benefit-to-cost ratio remained positive, as shown in table E-22. An in increase of over 80 percent in the interest rate would cause the benefit-to-cost ratio to fall below the 1.0 to 1.0 requirement. Decreasing the interest rate by the same percentages increases the degree of project feasibility.

Allowing the total first cost to increase or decrease will also effect the annual charges and benefit-to-cost ratio. A decline in total project first costs would have positive effects while an increase would negatively affect the amount of annual charges and the benefit-to-cost ratio. An increase of 90 percent in the total project first costs would reduce the benefit-to-cost ratio to less than 1.0.

One possible source of a project cost increase involves mitigation for cultural resources impacted by the project. A small degree of uncertainty is evident due to the incomplete cultural resource inventory for the channel and locations for depositing construction fill. There is the possibility that significant cultural resources that may be identified in remaining inventory efforts or through emergency discoveries during construction.

Another possible cost increase could be in the construction of the box culvert. Additional shoring may be required, although the estimate includes a reasonable estimate for this construction. The channel cost estimate would

have to increase by more than 171 percent (a 90 percent total project cost increase) before the plan would become unfeasible.

The likelihood of such a significant increase in channel costs or total project costs is considered remote given the 20 percent ceiling on project cost increases established in the Water Resource Development Act. Table E-23 shows the effects of increasing and decreasing the interest rate on the B/C ratio. Overall, the recommended construction on Hancock Creek does not appear to be significantly sensitive to any of the factors listed above.

Ability to Pay

Based on ER 1105-2-121 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 the study area must pass both the benefit and income portions of the two-fold ability-to-pay test.

The benefits test determines the maximum possible 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 benefit-to-cost ratio by four. The factor must fall inside the standard level cost share range of 25 to 50 percent. The Hancock Creek recommended plan's benefit-to-cost ratio of 1.9 was divided by four to yield a BBF of 0.48, within the aforementioned limits.

The next step, 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 State in which the project is located. In accordance with factors released in EC 1165-2-154, dated November 1989, the income index factors for the state of Texas and Travis County are 93.05 and 104.99, respectively. The Eligibility Factor (EF) for a flood control project is calculated according to the following formula:

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

where : $a = 14.24129$

$b_1 = 0.06104$

$b_2 = 0.12208$

Utilizing the above formula, an EF of -4.26 was calculated for Travis County. An EF less than or equal to zero does not qualify the Shoal Creek project for a reduction in cost sharing.

TABLE E-22

Benefit Cost Ratio Sensitivity To Changes in the Interest Rate

Interest Rate	Annual Charges	B/C Ratio	Percent+/-
6.56	$ 489,500	2.5	- 25%
7.88	$ 582,200	2.1	- 10%
8.75	$ 646,800	1.9	Current
9.62	$ 713,200	1.7	+ 10%
10.94	$ 816,000	1.5	+ 25%
15.80	$1,224,100	1.0	+ 81%

TABLE E-23

Benefit Cost Ratio Sensitivity To Changes in Total First Costs

First Cost	Annual Charges	B/C Ratio	Percent+/-
$ 4,976,025	$ 486,300	2.5	- 25%
$ 5,307,760	$ 518,400	2.4	- 20%
$ 5,971,230	$ 582,600	2.1	- 10%
$ 6,634,700	$ 646,800	1.9	Current
$ 7,298,170	$ 710,900	1.7	+ 10%
$ 7,961,640	$ 775,100	1.6	+ 20%
$ 8,293,375	$ 807,200	1.5	+ 25%
$12,600,000	$ 1,223,800	1.0	+ 90%

Financial Capability

A financial capability analysis of the City of Austin was conducted in accordance with ER 1105-2-100 to ascertain the community's financial condition and its ability to meet the cost sharing responsibilities for the Shoal Creek Project. The assessment involved the calculation and analysis of nine key financial indicators. The indicators were selected because of their importance in explaining the difference in credit worthiness between communities with strong credit and those with a weak credit rating. Table E-24 presents a summary of the data used in this analysis. Other relevant facts and data about the community will also play a role in the analysis. Table E-24 shows the rating system utilized in the analysis. The indicators, calculated values and corresponding rating using the 1984 edition of The Financial Capability Guide Book provided by the Environmental Protection Agency is shown in table E-26.

The annual rate of change in Austin's population, the first indicator, is considered weak at 0.5 percent over the past 5 years. The indicator is useful because the economic base typically rises and falls with changes in the population. The proportion of surplus/deficit expenditures to total expenditures is also a significant indicator of the community's strength. Austin is currently operating at a deficit with expenditures exceeding revenues by 29 percent, indicating a weakness. Projected expenditures provided by the city show the deficit declining over time. The third indicator measures the efficiency of the city's tax collection system. The city is currently strong in this area with a low level of tax delinquency. The city's reliance on tax revenue, indicator 4, shows the extensiveness of property taxation and the potential for future revenue growth from this source. Austin does not appear to tax heavily in relation to property values and displays a strong rating in this area.

Indicators 5 through 9 are used to assess the community's debt capacity. With the exception of indicator 9, the current and future debt situation of the city signifies a weakness in the remaining areas. Indicator 5 compares the amount of tax-supported debt to the full market value of real property. A value over 5 percent shows a weakness, while values between 3 and 5 percent are considered average. The city of Austin is marginally weak with a value of 5.3 percent. Personal income can be used as a yardstick to judge the city's ability to repay debt. Indicator 6 shows net debt representing about 10.9 percent of total personal income, which is average for most cities. Indicators 7 and 8 represent the per capita direct debt of over $1,200 and overall net debt of over $1,900, signifying a weakness.

Finally, indicator 9 compares the percentage of direct net debt due within 5 years to total direct net debt outstanding. The city's situation indicates strength in this area since the current payback period is short. However, this may indicate that debt service requirements are greater than the community can afford, especially since current expenditures exceed revenues. The analysis of all these factors, shows that the city should not take on new debt in the very near future. The overall financial condition of the community is currently in a marginally weakened state due to the large amount of net debt outstanding.

TABLE E-24

SUMMARY OF FINANCIAL CAPABILITY
SHOAL CREEK, AUSTIN, TEXAS, FEASIBILITY STUDY

COMMUNITY'S DEBT HISTORY

A. BOND RATINGS	Rating	Date
General Obligation	AA	Sept '89
Revenue Bond	A	July '89

B. DEBT	Outstanding	Total
General Obligation Bonds	$449,738,455	$449,738,455
Revenue Bonds	98,240,000	98,240,000
Gross Direct Debt	546,978,455	546,978,455
Direct Net Debt	540,369,399	540,369,399
Overlapping Net Debt[1]	395,835,164	395,835,164
Overall Net Debt		936,204,563

C. DEBT REPAYMENT SCHEDULE (principal only)	Outstanding Total
Year 1	$ 64,241,902
Year 2	63,681,486
Year 3	62,473,454
Year 4	61,044,799
Year 5	59,771,286
Direct Net Due in 5 Years	$311,212,927

D. DEBT LIMITS

The legal authority for local sponsor to assume debt is authorized by State Law and requires voter authorization by City Charter. The limits are determined by the city council.

[1] Overall net debt is the sponsor's share of taxes owed to other taxing bodies within the community, ie., a flood district.

TABLE E-25

Financial Indicator Rating Key

Indicator	Weak	Average	Strong
1. Annual rate of change in population	< 1%	1% to 1%	> 1%
2. Current surplus/deficit as a percent of total current expenditures	< 0%	0% to 5%	> 5%
3. Real property tax collection rate	< 96%	96% to 98%	> 98%
4. Property tax revenue as a percent of full market value of real property	> 4%	2% to 4%	< 2%
5. Overall net debt as a percent of full market value of real property	> 5%	3% to 5%	< 3%
6. Overall net debt outstanding as a percent of personal income	> 12%	4% to 12%	< 12%
7. Direct net debt per capita	> $750	$250 to $750	< $250
8. Overall net debt per capita	> $1,000	$450 to $1,000	< $450
9. Percent direct net debt outstanding due within next 5 years	> 10%	10% to 30%	< 30%

TABLE E-26

Current Community Financial Indicator Values For The City Of Austin

INDICATOR	VALUE	RATING
1. Annual rate of change in population	0.5%	Weak
2. Current surplus/deficit as a percent of total current expenditures	-29.0%	Weak
3. Real property tax collection rate	98.9%	Strong
4. Property tax revenues as a percent of full market value of real property	0.6%	Strong
5. Overall net debt as a percent of full market value of real property	5.3%	Average to Weak
6. Overall net debt outstanding as a percent of personal income	10.9%	Average
7. Direct net debt per capita	$1,128	Weak
8. Overall net debt per capita	$1,954	Weak
9. Percent direct net debt outstanding due within next 5 years	58.0%	Strong

A number of factors have led to the marginally weak financial condition of the city of Austin. The city's financial condition is consistent with many other cites in Texas that experienced tremendous growth during the 1980 to 1985 period. The increased population placed greater demands on the city to provide services, repair and build the infrastructure, water treatment plants and other capital improvements. These improvements along with the decline in the Texas economy during the mid 1980's have served to increase debt. The impact of these finds on the Shoal Creek project is presented below in the section entitled non-Federal Financial Plan.

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, if needed; 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 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.

Currently the city of Austin is in a weakened financial state. This previously was shown in the financial capability analysis. In a letter from the city's Transportation and Public Works Department (see appendix A) the city submitted data for the financial capability analysis and a summary of current and future financial obligations. Based on the city council's recently adopted financial policy to limit general obligation bond sales to $25 million per year, it would be four to five years before current unissued authority is depleted. Funding for several Shoal Creek improvements between 1982 and 1984 along with public demand for flood control improvements in other parts of the city has reduced the likelihood of additional authorization. Although the public could authorize the issuance of general obligation bonds for the recommended project there is no evidence of city plans to obtain additional funding authority for Shoal Creek from the Austin electorate during the 1990 fiscal year. Therefore, assumptions were formulated which acknowledge the conditions under which financing for the Shoal Creek project could be obtained.

Since financial policies are subject to change as local economic conditions improve, the possibility exists for the Shoal Creek project to be considered for funding. In addition, weather conditions could increase public demand for immediate flood control improvements in this area. Manifestation of some or all of the provisions outlined below would serve to the city's capability of obtaining financing. Under the conditions assumed above, the city should be able to secure financing within the construction time frame beginning in 1996.

- The federal government could defer payments based on options available under section 103 of P.L. 99-662.

- Front-end costs could be paid by the Federal government.

- Additional debt could be authorized by the electorate by 1992.
- Overall net debt and the disparity between revenues and expenditures could continue to decrease.

The Corps of Engineers has been working with the city of Austin to develop an approach to financing the pending project. Presently the city of Austin is not in a financial or authoritative position which will allow officials to commit to financing of the Hancock Creek Project in the 1990 fiscal year. However, the funding problems appear to be short term as evidenced by the debt repayment schedule previously shown in table E-24. Efforts to improve the city's financial condition would occur during the Engineering and Design phase. The city is optimistic that future economic conditions could improve to a level which will permit additional authority for bond issuance to be granted.

APPENDIX F

GEOTECHNICAL ANALYSIS

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APPENDIX F

SHOAL CREEK
AUSTIN, TEXAS

GEOTECHNICAL ANALYSIS

GENERAL

The selected plan includes improvements on Shoal Creek and on Hancock Creek. Improvements on Shoal Creek include two diversion tunnels as well as channel improvements. The improvement on Hancock Creek consists of channel improvements and construction of a box culvert. A detailed description of the project is contained in the main report.

Shoal Creek. Improvements on Shoal Creek include two 14- foot diameter diversion tunnels and a channel improvement. The two diversion tunnels are referred to as the "Northwest Park Tunnel" and the "19th Street Tunnel." The Northwest Park Tunnel will be approximately 14,000 feet in length and extends from a shaft inlet on Shoal Creek at Northwest Park to an outfall portal on Lake Austin approximately 1,500 feet downstream of the confluence of Bull Creek with Lake Austin. The 19th Street Tunnel extends approximately 5,000 feet from a shaft inlet on Shoal Creek in Pease Park near 19th Street to an outfall portal on Town Lake near Pressler Street. The channel improvement on Shoal Creek extends downstream from the MOPAC railroad through Highway 183 to Foster Lane.

Hancock Creek. Channel improvements on Hancock Creek extend from Houston Street downstream through Burnet Road and Hancock Drive to a point approximately 700 feet downstream of Hancock Drive. Hancock Creek passes beneath Burnet Road and an adjacent shopping center within the confinement of a box culvert. The improvement on Hancock Creek includes the construction of an additional 10-foot by 10-foot box culvert which will be routed around buildings within the shopping center.

SUMMARY OF INVESTIGATIONS

Geologic evaluation for the Shoal Creek Flood Control Study has been restricted to assistance with economic comparison of channel improvement versus tunnel construction. Investigations have been limited to literature research and surface reconnaissance. Surface geology (including known faulting) and ground-water conditions have been projected to potential tunnel depth on conceptual alignments (see Exhibit F-1) chosen with intake sites nominated by the Flood Control Branch, Planning Division, with minimum distance alignments and outlets on Lake Austin and Town Lake. The projected subsurface information has been translated to tunnel construction cost data. Comparative construction costs have been furnished to CESWF-PL-P for variable diameter tunnels with variable rock conditions using precast concrete liners.

Reconnaissance was performed along the Shoal Creek streambed to estimate type and quantity of rock excavation. Results were furnished on selected cross sections to CESWF-ED-DC.

Two core borings were made in 1983 along a previous alignment for the Northwest Park tunnel. Further subsurface investigations were placed on hold pending economic benefit and cost studies.

PHYSIOGRAPHY AND REGIONAL GEOLOGY

The Austin Area is located at the boundary between two physiographic provinces - the Edwards Plateau and the Coastal Plain. This region extends from the dissected margin of the Edwards Plateau (the hill country) crosses the transitional boundary of the complex Balcones fault zone, whose western limit is marked by the Mount Bonnell fault, and then crosses the rolling Blackland Prairie Belt of the Coastal Plain to the edge of the Post Oak Sand Belt of the Coastal Plain. The study area is within a gently southeast dipping homocline disrupted by the Mount Bonnell fault and numerous small faults comprising the Balcones fault zone, which is a belt of northeast trending dip-slip normal faults in which the differential movement has been down the fault planes. Mount Bonnell fault is the major structural feature of the area and has a displacement of about 600 feet, but most fault displacements are less than 50 feet. About 60 percent of the faults are downthrown to the east, about 40 percent to the west. Drag folding exists on the west side of Mount Bonnell fault in the Glen Rose Formation.

Elevations of the hill country vary from 500 to more than 1,000 feet and are characterized by moderate to steep slopes. East of the city the Blackland Prairie topography is mainly rolling, and the ground surface elevation ranges between 500 and 800 feet. Topographic elevations within the conceptual tunnel projections vary from just over 800 to just under 500 feet.

The study area is within the drainage of the Colorado River which flows from northwest to southeast and drains Shoal Creek, as well as Bull and Boggy Creeks. Bedrock near the Colorado River is locally mantled by floodplain and river terrace deposits. Bedrock along the tributaries is exposed, or is variably covered by stream alluvium.

Both the hill and prairie country are underlain by Cretaceous age sedimentary rocks cropping out in north-northwest trending belts with progressively younger formations exposed toward the east.

SITE GEOLOGY

Projection of surface lithology and geologic structure to potential tunnel depth indicates the following geologic conditions:

a. Northwest Park Tunnel. - The proposed inlet shaft will be about 92 feet deep and will encounter approximately 25 feet of alluvial soils underlain by chalky limestone of the Austin Formation. Based on published geologic maps, the tunnel alignment will cross two major fault zones

within 2,000 feet of the inlet shaft. The tunnel excavation will be in the following geologic formations from inlet shaft to downstream outlet: Austin Chalk, Eagle Ford/Buda Formation and the Glen Rose Limestone (see exhibit F-2 for geologic profile).

b. 19th Street Tunnel. - The proposed inlet shaft will be approximately 55 feet deep and will be within the Georgetown Limestone. The tunnel excavation will likewise be excavated in the Georgetown Formation. Based on published geologic maps, the downstream tunnel portal will be faced in alluvial terrace deposits underlain by the Georgetown Formation. The proposed tunnel portal location provides a very minimal thickness of burden above the portal crown.

Exhibits F-4 and F-5 summarize characteristics of rock units in the study area. Exhibits F-6 and F-7 are geologic logs of two borings which were drilled on a former Northwest Park tunnel alignment.

GROUND WATER

Ground-water conditions along the alignment of the conceptual tunnels have been studied only by review of available literature. Within the two borings drilled along a former Northwest Park tunnel alignment, the ground-water level was at elevation 628.5 in NX-2, and elevation 671.4 in NX-1 after hole completion. Pressure tests were not made. These two readings are not regarded as significant, except in relationship to future data. Detailed ground-water conditions will be determined from future investigations.

Tunnel excavations are expected to encounter ground water in the major fault zones. The ground water will be controlled by grouting ahead of the tunnel bore or by pumping from the tunnel excavation.

DISCUSSION AND DESIGN RECOMMENDATIONS

General. Detailed geotechnical investigations beyond site reconnaissance and research of existing data have been deferred to future design phases. Geotechnical design recommendations at this stage are, therefore, tentative and will be subject to refinement. The surface construction (such as channel improvements and bridge and utility relocations) is standard design; therefore, the construction cost estimates do not require additional comment. The recommended tunnel configuration will be described below, however, so that assumptions made for the purpose of cost estimation can be validated. Additionally, several design issues which will require resolution during future design phases have been identified and will also be discussed.

Tunnel Configuration, General. The following assumptions have been made for cost estimating purposes: (a) Except in the portal areas and in the transitions areas at the inlet shafts, tunnels will be lined with precast concrete liners; (b) Where precast liners are used, tunnel excavation will be by a tunnel boring machine (TBM); (c) A (very conservative) uniform confining pressure of 10 KSF has been assumed for liner design;

TABLE 1. GENERAL CHARACTERISTICS AND ENGINEERING PROPERTIES OF GEOLOGICAL UNITS, AUSTIN WEST QUADRANGLE.

EXHIBIT F-4

GEOLOGIC UNIT	MAP SYMBOL	THICKNESS (feet)	GENERAL CHARACTERISTICS	ENVIRONMENTAL GEOLOGIC CHARACTERISTICS: SLOPE STABILITY	EXCAVATION CHARACTERISTICS	FOUNDATION CHARACTERISTICS	INFILTRATION CAPACITY	ROCK AND MINERAL RESOURCES	ENGINEERING TEST DATA: UNIT WEIGHT (lbs./cu. ft.)	MOISTURE (% by weight)	SEISMIC VELOCITY (feet/second)	TRIAXIAL COMPRESSION (tons/sq. ft.)	UNCONFINED COMPRESSION (tons/sq. ft.)	PLASTICITY INDEX (Atterberg Limits)	ABSORPTION SWELL (%)	ABSORPTION PRESSURE (lbs./sq. ft.)
Alluvium	Qal	0-20	Unconsolidated gravel, sand, silt, and clay of tributary streams; includes flood-deposited material immediately below Tom Miller Dam.	Moderate to low--commonly water saturated	Readily excavated by light machinery	Bearing capacity moderate to low; shrink-swell low to high	Generally high with adequate absorption of septic tank effluent; may be saturated seasonally and have low fluid acceptance	Minor source of sand and gravel. Yields small variable supplies of water; supply subject to drought	81 to 107	3 to 70	1,000 to 2,500	0.5 to 2.5	0.1 to 5.16 (mostly under 3.0)	4 to 60 (mostly 20 to 60)	0.5 to 6.75	600 to 8,400
Colorado River Terrace Deposits Sand Beach Riverview First Street Sixth Street Capitol Asylum	 Qsb Qrv Qfs Qss Qca Qas	 0-40 0-40 0-40 0-25 0-30 0-25	Mostly unconsolidated, yellow- to orange-brown gravel, sand, silt, and clay; consists mostly of Cretaceous limestone and chert fragments with minor amounts of older igneous, sedimentary, and metamorphic rocks. Gravel more common in higher (older) units, and more abundant near base of each unit. Upper surface of First Street terrace is level of maximum recorded flood (1869, 1935). Lower three units partly or completely flooded above Tom Miller Dam. Lower two units were frequently flooded prior to regulation of flow by Colorado River dams. Terrace deposits above flood level support growths of live oak and post oak.	Moderate to low	Readily excavated by light machinery	Bearing capacity moderate to low; large structures may require special design; shrink-swell low to moderate	Generally high with adequate absorption of septic tank effluent; lower units may be saturated and have low fluid acceptance	In the past supplied much sand and gravel; now mostly urbanized. May yield substantial supplies of water, more in lower terrace deposits	82 to 123	2 to 35	1,000 to 2,500	0.1 to 3.5	0.5 to 7.3 (mostly under 4.0)	8 to 66 (mostly 10 to 40)	0.03 to 3.5	400 to 8,400
Tributary Terrace Deposits	Qt	0-20	Mostly unconsolidated, light gray to tan, gravel, sand, silt, and clay; consists of locally derived limestone and chert gravel and calcareous silt and clay. Forms terraces along Barton Creek, Bull Creek, Shoal Creek, and other smaller creeks; includes minor, topographically high, alluvial deposits not directly related to modern streams.	Moderate to low	Readily excavated by light machinery	Bearing capacity moderate to low; shrink-swell low to moderate	High; adequate absorption of septic tank effluent	Potential source of sand and gravel; some previous operations now urbanized. May yield minor supplies of water	82 to 120	3 to 40	1,000 to 2,500	0.7 to 5.0	1.0 to 4.0	7 to 55 (mostly 20 to 40)	0.0 to 7.5	200 to 6,400
Austin Group Vinson Formation	Kvs	50	Gray to white, thin- to thick-bedded, massive chalk. Forms light-colored, moderately dissected slopes with live oak and juniper. Thickness incomplete; only lower part of each unit exposed.	High	Difficult to excavate with light equipment; generally can be ripped with heavy equipment	Bearing capacity high; shrink-swell generally low	Low to moderate; marginal to adequate absorption of septic tank effluent	None in this area; potential cement raw material elsewhere in Austin area	87 to 123	10 to 30	4,000 to 6,000	*	10 to 250 (mostly over 40)	10 to 40 (marly units)	0.1 to 0.8	400 to 1,400
Atco Formation	Kat	80	Gray to white, thin- to thick-bedded, massive to slightly nodular, fine-grained limestone, marly limestone, and chalk.													
Eagle Ford Formation	Kef	40	Upper part is dark gray clay; middle part consists of thin interbeds of sandy and flaggy limestone, chalk, clay, and bentonite; lower part is mostly dark gray calcareous clay. Includes Pepper Shale at base--soft, laminated, non-calcareous, three feet thick. Generally forms grassy, low relief areas with few native trees.	Low to moderate; decreases with increasing moisture content	Moderately easy to excavate; limestone and sandstone beds may require ripping	Bearing capacity generally low; may need special foundation design or excavation down to Buda Limestone; high shrink-swell	Low; generally inadequate absorption of septic tank effluent	None in this area	80 to 115	10 to 45	2,000 to 8,000	0.7 to 8.0	1 to 300 (clays mostly under 10; thin limestone and sandstone beds mostly over 60)	8 to 70 (mostly 20 to 50)	0.1 to 3.8	800 to 2,600
Buda Formation	Kbu	35	Gray to tan, hard, fine-grained, glauconitic, shell fragment limestone. Lower part less resistant and slightly nodular weathering. In outcrop fresh surfaces yellowish to pink. Commonly forms steep slopes above the Del Rio Clay. Live oak, juniper, elm, and hackberry are common on this unit.	Generally high but may fail at edges of steep slopes above weak Del Rio Clay	Excavation difficult; generally requires blasting	Bearing capacity generally high, but may be low at outcrop edge above slopes of Del Rio Clay	Low	None	*[2]	*	8,000 to 11,000	*	60 to 420	*	*	*
Del Rio Clay	Kdr	75	Dark gray to olive brown, pyritic, gypsiferous, calcareous clay containing abundant Exogyra arietina (ram's horn oyster). Poorly exposed in steep to shallow slopes below Buda limestone. Del Rio slopes readily fail by slide and creep; slopes commonly covered with a thin layer of Buda limestone rubble which supports typically limestone vegetation of live oak and juniper. Elsewhere the Del Rio supports only a cover of grass and scattered mesquite trees.	Low; decreases with increasing moisture content; fails when wet on shallow slopes	Moderately easy to excavate with light machinery	Bearing capacity low; structures need special support; high shrink-swell	Low; inadequate absorption of septic tank effluent	None	100 to 123	10 to 30	2,000 to 4,500	1.5 to 2.5	3 to 20 (mostly under 10)	20 to 56 (mostly 30 to 50)	4.7 to 8.4	4,400 to 6,600
Georgetown Formation	Kgt	55	Thin interbeds of gray to tan, nodular weathering, hard, fine-grained limestone, marly limestone, and marl, containing abundant fossil shells. Forms moderate to shallow slopes above more resistant Edwards limestone. Supports a limestone vegetation with juniper especially abundant.	High	Excavation difficult; blasting generally required	Bearing capacity high; no special support needed	Low	None	*	*	7,000 to 9,000	*	40 to 300 (mostly over 100)	*	*	*

TABLE 1. GENERAL CHARACTERISTICS AND ENGINEERING PROPERTIES OF GEOLOGICAL UNITS, AUSTIN WEST QUADRANGLE.

EXHIBIT F-5

GEOLOGIC UNIT	MAP SYMBOL	THICKNESS (feet)	GENERAL CHARACTERISTICS		ENVIRONMENTAL GEOLOGIC CHARACTERISTICS: SLOPE STABILITY	EXCAVATION CHARACTERISTICS	FOUNDATION CHARACTERISTICS	INFILTRATION CAPACITY	ROCK AND MINERAL RESOURCES	ENGINEERING TEST DATA: UNIT WEIGHT (lbs./cu. ft.)	MOISTURE (% by weight)	SEISMIC VELOCITY (feet/second)	TRIAXIAL COMPRESSION (tons/sq. ft.)[1]	UNCONFINED COMPRESSION (tons/sq. ft.)	PLASTICITY INDEX (Atterberg Limits)	ABSORPTION SWELL (%)	ABSORPTION PRESSURE (lbs./sq. ft.)
Edwards Formation Member 4	Ked_4	40	Mostly hard, dense, gray to tan, thick- to thin-bedded, fine-grained limestone; soft, dolomitic near middle; lower part flaggy bedded.	Forms weakly to deeply dissected topography mostly east of Mount Bonnell fault. Members 1, 2, and 4 generally support growths of oak, juniper, hackberry, persimmon, and other plants.	High	Excavation difficult to moderate; blasting generally required	Bearing capacity high; no special support needed	Low in fine-grained dense limestones, moderate to high in coarse-grained limestones, dolomites, and cavernous zones	Source of high-grade crushed stone; large quarry in northeast map area recently urbanized. Lower Ked_4 was source of dimension stone (Austin Marble and paving flags). Ked_1 is important aquifer; source of Barton Springs and other springs	*	*	7,000 to 11,000	*	95 to 300 (mostly over 200)	*	*	*
Member 3	Ked_3	10	Mostly soft, nodular weathering, gray to tan, marly limestone, with abundant growth of juniper.														
Member 2	Ked_2	40	Mostly hard, light gray to tan, fine- to medium-grained, thin- to thick-bedded limestone; thin beds mostly fine grained, flaggy; thicker beds coarser grained with abundant rudist fragments and miliolid foraminifers. Chert nodules in lower third.														
Member 1	Ked_1	200	Mostly thin- to medium-bedded, gray-brown, porous dolomite and dolomitic limestone, and gray to tan, fine- to medium-grained rudist limestone. Nodular chert common. Top of unit is a 20-foot cavernous, solution-collapse zone. Total thickness estimated; complete section not exposed.														
Walnut Formation Bee Cave Member	Kbc	30	Soft, gray to tan, nodular weathering, fine-grained limestone, marly limestone, and marl with abundant fossil shells. Forms steep, light-colored, juniper-covered slopes on high topography west of Mount Bonnell fault.		Moderate to high	Excavation moderate to difficult, probably rippable in part	Bearing capacity moderate to high; special support generally not needed	Low to moderate; absorption of septic tank effluent probably marginal	Minor source of road material	*	*	3,000 to 7,000 (estimated)	*	50 to 200 (estimated)	*	*	*
Bull Creek Member	Kbk	35	Hard, dense, gray to tan, fine- to medium-grained, thin- to thick-bedded limestone; shell fragments and miliolid foraminifers common. Forms prominent bench on high topography west of main fault. Limestone vegetation of live oak, juniper, hackberry, and other plants.		High	Excavation difficult; blasting required	Bearing capacity high; no special support needed	Low to moderate	Minor source of road material	*	*	7,000 to 11,000 (estimated)	*	100 to 300 (estimated)	*	*	*
Glen Rose Formation Member 5	Kgr_5	100	Mostly thin-bedded, gray-brown, fine-grained, porous dolomite; upper 10 to 20 feet pulverulent.	Forms moderately to deeply dissected hill country west of main fault. Typified by stair-step topography with oak-juniper vegetation.	High to moderate	Excavation difficult to moderate; blasting commonly needed	Bearing capacity generally high to moderate; thin, weak marl beds can be excavated down to harder, more stable limestone beds	High in dolomitic units; moderate to low in other units	Minor source of road material; dolomitic members are minor aquifers	*	*	3,000 to 10,000 (estimated)	*	90 to 250 (estimated)	*	*	*
Member 4	Kgr_4	120	Gray to tan, mostly thin- to thick-bedded, fine- to medium-grained limestone and marly limestone. Many beds with fossil shells.														
Member 3	Kgr_3	70	Gray brown to tan, thin interbeds of dolomite, dolomitic limestone, limestone, and marly limestone.														
Member 2	Kgr_2	120	Gray to tan, thin to thick interbeds of fine- to medium-grained limestone, marly limestone, and marl. Many beds with fossil shells.														
Member 1	Kgr_1	30	Gray to tan, thin- to thick-bedded limestone, marly limestone, and marl. At top is thin, orange-brown limestone ledge with abundant small fossil clams (Corbula harveyi); underlying marly limestone abundantly fossiliferous. Thickness is minimum; lower contact not exposed.														

1/ Derived partly from penetrometer correlation bearing curves of the Texas Highway Department

2/ *Test not applicable or test data not available

and (d) An average 10 mile haul (one-way) will be required for disposal of excavated materials.

Tunnel Configuration, Shafts and Portals.

a. Northwest Park Tunnel. For the purpose of estimation of construction cost, it has been assumed that the transition zone between the inlet shaft and the tunnel will be mined by conventional methods and that some rockbolts and other temporary support will be required to construct the transition. Cast-in-place lining will be required in the transition zone. Additionally, it has been assumed that 100 feet of the tunnel at the outfall end will also require temporary support (steel sets and shotcrete) and cast-in-place lining will be used.

b. 19th Street Tunnel. Construction cost estimates for the 19th Street Tunnel also include allowance for support and conventional mining procedures at the transition between the shaft and the tunnel. At the outfall end, 600 feet of the tunnel will require the following construction: The first 150 feet of the tunnel at the outfall end will consist of a cut-and-cover conduit due to the proximity of the ground surface. The conduit has been assumed to be cast-in-place. The end of the cut-and-cover construction will be at the face of the bluff where the tunnel passes under two railroad tracks. The tunneling, for a distance of 450 feet from the end of the cut-and-cover conduit, has been assumed to require conventional excavation and temporary support (steel sets and shotcrete). This portion of the tunnel will also require cast-in-place lining. It has been assumed that the 150-foot cut-and-cover segment of the tunnel will be constructed after other portions of the tunnel are complete.

The construction cost estimate for the 19th Street Tunnel includes the cost for bridges for the two railroad tracks which will pass over the tunnel. This has been assumed to be required to prevent problems associated with settlement of the tracks.

Unresolved Design Issues. Several design features will have to be resolved during future design phases. These include: (a) The configuration of the 19th Street Tunnel outfall; (b) Final tunnel alignments and depths; (c) Bypass of the existing city of Austin Crosstown Wastewater Interceptor Tunnel by the Northwest Park Tunnel; and (d) The configuration of the Hancock Creek box culvert. The construction cost estimates are believed to be adequate to cover design changes required during future design phases due to these unresolved design issues. Each of these design issues will be discussed below.

a. 19th Street Tunnel Outfall. The portal for the 19th Street Tunnel will be faced in alluvial terrace deposits with a minimal thickness of burden. The cost estimate includes contingencies for additional support which will be required within the alluvial materials. Three design options for configuration of the tunnel portal may be considered during future design phases. These are: (1) Engineering feasibility of the present configuration will be re-evaluated after subsurface conditions are better defined; (2) Cut-and-cover will be re-evaluated as an option; or

(3) The tunnel outfall may be reconfigured as an inverted siphon nearer Town Lake to lower the tunnel profile into sounder materials and to eliminate required modifications under the Mopac Railroad and existing roads. Each of these configurations may be considered with respect to engineering and economic feasibility during future design phases. It is not anticipated that conclusions concerning economic feasibility of the project will be affected.

b. Final Tunnel Alignments and Depths. Proposed tunnel alignments are "straight line" alignments from inlet to outfall. During future design phases, minor adjustments to the tunnel alignments and depths may be required for optimization of tunneling conditions, to avoid deep foundations or other obstacles, or to optimize real estate acquisition. Detailed geotechnical and structural investigations will include investigation of faulting and survey of buildings or other structures which may require adjustment of tunnel alignments.

c. Bypass of the Existing Crosstown Wastewater Interceptor Tunnel. The Northwest Park Tunnel alignment will cross the existing interceptor tunnel approximately 2,000 feet upstream of the proposed tunnel outfall. The invert of the proposed tunnel will lie about 15 feet above the crown of the interceptor tunnel. The alignments of the tunnels will cross at a near perpendicular angle. When final tunnel alignments and profiles are defined, an assessment of the required design elements will be performed to ensure the integrity of both tunnels.

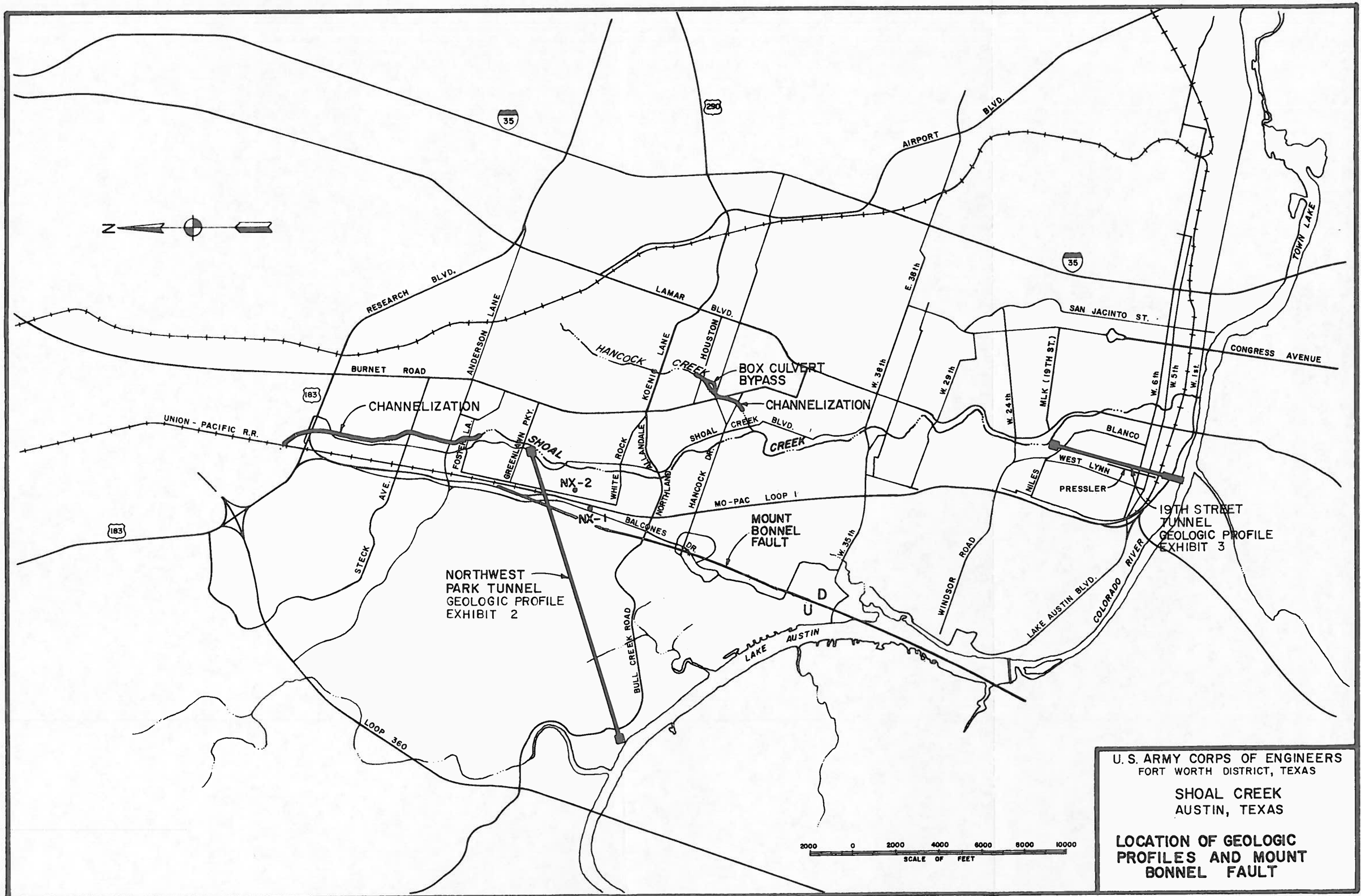
d. Hancock Creek Box Culvert. Hancock Creek passes beneath a small shopping center within a box culvert. The proposed project includes the construction of an additional box culvert through the shopping center to provide additional conveyance. The proposed 10-foot by 10-foot box culvert will pass between two buildings beneath an existing driveway which is approximately 18 feet wide. The owners of the shopping center were contacted in an effort to acquire as-builts of the buildings, but none were obtained. It is believed that the small single story building to the south of the proposed box culvert alignment is founded on continuous footings or on a slab on grade with downturned edges. The small single story department store building to the north of the culvert is believed to be founded on spread footings or on drilled shafts to limestone bedrock 10 to 12 feet below the existing ground surface. Based on these conditions, it was recommended that 10 feet would be the maximum safely constructible width for the proposed box culvert. To prevent damage to the existing buildings, it is recommended that a drilled shaft retaining wall be used to form the sides of the box. A pre-cast or cast-in-place cover will restore the driveway for the use of the shopping center. During future design phases, the as-built condition of the two buildings will have to be documented to determine whether the width (and/or depth) of the box culvert has to be varied.

<u>Additional Design Recommendations.</u> Conservative soils design parameters (which will not be presented herein) have been assumed for tentative design of structural foundations and for design of slopes and other features of the project. Soils which will be encountered during surface construction will be variable mixtures of sandy and silty clays with some

gravel and cobbles. Generally, rock will be encountered at or very near the existing grade of Shoal or Hancock Creeks. Soils will be much deeper at the tunnel outfall sites. It is anticipated that rock excavated for surface construction will require heavy ripping with some blasting in isolated areas. As noted previously, an average haul of 10 miles to disposal sites has been assumed for cost estimating purposes. Approximately 700,000 cubic yards of materials will have to be wasted.

CONCLUSIONS

The project appears to be geotechnically feasible after resolution of minor design details. Current construction cost estimates are believed to be adequate to provide for design changes which may be required during future design phases. Refinement of the project design will require extensive geotechnical investigations and analyses.

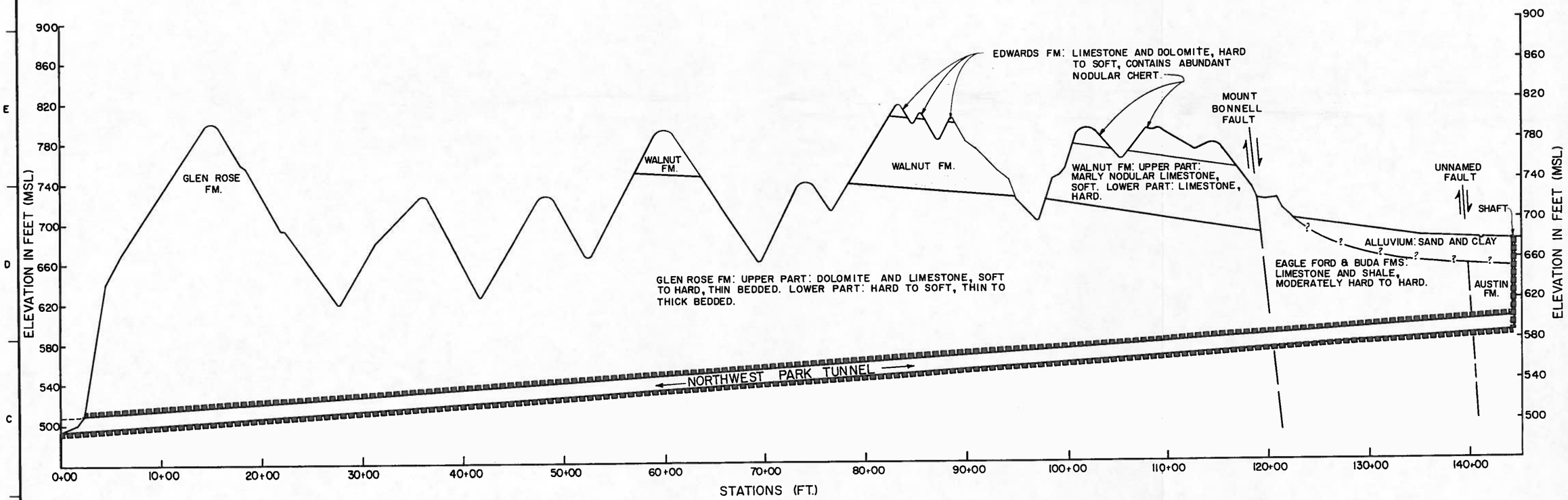


U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT, TEXAS

SHOAL CREEK
AUSTIN, TEXAS

LOCATION OF GEOLOGIC PROFILES AND MOUNT BONNEL FAULT

EXHIBIT F-1



NOTES

1. GEOLOGIC CONTACTS ARE APPROXIMATE, BASED UPON PUBLISHED GEOLOGIC MAPS.
2. FOR LOCATION OF PROFILE, SEE EXHIBIT F-1.

REV. NO.	NO.	ACTION	DATE	DESCRIPTION OF REVISION

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

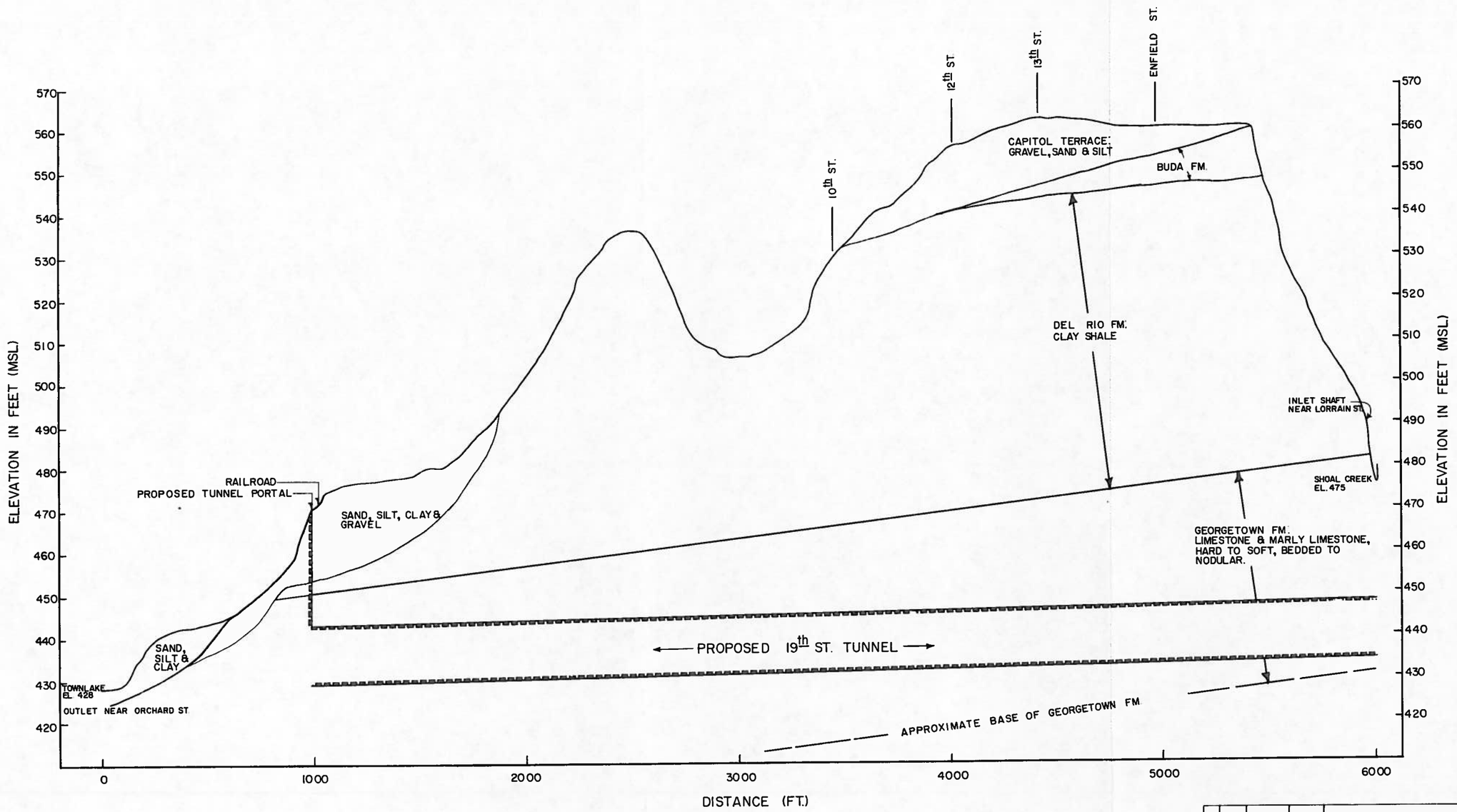
DESIGNED BY: G. RUEDE
DRAWN BY: C. KIRBY
REVIEWED BY: R. BEHM
SUBMITTED BY: ROBERT C. BEHM
ENGINEER:

SHOAL CREEK
AUSTIN, TEXAS

GENERALIZED GEOLOGIC PROFILE
PROPOSED NORTHWEST PARK TUNNEL

SOL. NO.
DATED: SEPT. '89
CONTR. NO.
DRAWING NUMBER
SHEET NO. OF
SEQUENCE NO.
CONTR. NO.

EXHIBIT F-2



NOTES

1. GEOLOGIC CONTACTS ARE APPROXIMATE, BASED UPON PUBLISHED MAPS.
2. FOR LOCATION OF PROFILE, SEE EXHIBIT F-1.

REVISION NO.	REVISED	DATE	DESCRIPTION OF REVISION

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

DESIGNED BY: G.RUEDE
DRAWN BY: C.KIRBY
REVIEWED BY: R. BEHM
SUBMITTED BY: ROBERT C. BEHM
ENGINEER:

SHOAL CREEK
AUSTIN, TEXAS

GENERALIZED GEOLOGIC PROFILE
PROPOSED 19th ST. TUNNEL

SOL. NO. | DATED SEPT. '89
CONTR. NO.
DRAWING NUMBER | SHEET NO. OF | SEQUENCE NO.

EXHIBIT F-3

Hole No. #1 NX-1

DRILLING LOG	DIVISION S-	INSTALLATION Ft Worth	SHT 1 OF 1 SHEETS

1. PROJECT Shoal Creek, Austin, Tx.	10. SIZE AND TYPE OF BIT *
2. LOCATION (Coordinates or Station) EC-60 Offset	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) #1 NX-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED – ; UNDISTURBED
5. NAME OF DRILLER Brewer/Degrate	14. TOTAL NUMBER CORE BOXES 3
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER ***
7. THICKNESS OF OVERBURDEN 2.0'	16. DATE HOLE: STARTED 29 Sept 83; COMPLETED 30 Sept 83
8. DEPTH DRILLED INTO ROCK 137.7	17. ELEVATION TOP OF HOLE approx. 730'
9. TOTAL DEPTH OF HOLE 139.7'	18. TOTAL CORE RECOVERY FOR BORING 100 %
	19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION 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
	99.8		0.0 to 99.8' - Rockbit.			* Drilling 0.0 to 99.8' - 4½" rock-bit, 99.8 to 139.7' - 2" diamond core.
			99.8 to 139.7 LIMESTONE - no apparent dips or weathering, various shades of white and gray, some medium bedding to mostly massive, fine to dense, moderately hard to hard (rock classification), slightly fossiliferous, scattered stylolitic structures through-out, very sl. vuggy @ 100', vuggy from 108.5 to 110.3'.	L 0.0 RQD= 100%		*** Hole bailed. 72 hr. check @ 58.6'. Note; Hole offset 50' east of proposed hole.
	109.8				Box 1	No samples taken. All core boxed and moved to Ft Worth. Core boxes had four columns and were either four or five feet in length.
				L 0.0 RQD= 88%		Rock Quality Designation RQD = all core recovered over 4" within a pull and indicated as a % of total recovery.
	119.8					Hole grouted up to surface.
				L 0.0 RQD= 99%	Box 2	
	129.8					
				L 0.0 RQD= 100%	Box 3	
	139.7					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT

HOLE NO. NX-1

EXHIBIT F-6

DRILLING LOG

1. PROJECT: Shoal Creek, Austin, Tx.	10. SIZE AND TYPE OF BIT: 9
2. LOCATION (Coordinates or Station): approx. 15 + 50	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): #2 NX-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED – ; UNDISTURBED
5. NAME OF DRILLER: Brewer/Degrate	14. TOTAL NUMBER CORE BOXES: 2
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: approx. 689'
7. THICKNESS OF OVERBURDEN: ?	16. DATE HOLE: STARTED 28 Sept 83; COMPLETED 28 Sept 83
8. DEPTH DRILLED INTO ROCK: ?	17. ELEVATION TOP OF HOLE:
9. TOTAL DEPTH OF HOLE: 75'	18. TOTAL CORE RECOVERY FOR BORING: %
	19. SIGNATURE OF INSPECTOR: Robert McVey

ELEVATION 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
	39'		0.0 to 39' - rockbit.			* Drilling 0.0 to 39' - 4½" rockbit, 39 to 75' - 2" core; carbon until 59', then diamond.
			39 to 39.6 LIMESTONE - weather stained yellowish brown, white, ~~unit varies~~ from coarse to fine grained and to dense, massive to thinly bedded, carbonaceous, moderately hard (rock classification).	L0.5' RQD= 84%	Box 1	*** Hole went blind @ 58'. Hole not bailed. 24 hr. check @ 60.6'. 36 hr check @ 60.5'. Grout filled until 8" from surface, then asphalt.
	49'		39.6 to 55.2 SHALE - mostly an unweathered dark gray, local weather stained yellow brown section from 54.7 to 55.1', mod. soft (rx class), massive, numerous very thin very limey/l.s. seams and lenses scattered throughout, limestone seam at 41.7 to 42', open high angle fracture @ 39.9', and from 42.8' to 43.1', shale gets softer after 48.7', also more plastic consistency.	RQD= 100% L3.0' all actual loss L0.5' RQD= 64%	Box 1	Core boxes each had four columns and were five feet in length. RQD = all core recovered over 4" within a pull and indicated as a % of total recovery.
	59'		55.2 to 75.0 LIMESTONE - weather stained yellow brown and white until 63.9', then an unweathered dark gray, massive to ~~medium bedded~~, dense to fine crystalline structues, granular appearing locally, mod. hard with a few thin mod soft shale seams (rock class), green minerals @ 71.3', styolitic structures scattered throughout, slightly vuggy throughout, scattered cavity and fracture fills that are mod. to well cemented, slicks @ 71.3', shale seams from 67.8 to 70.3', slicks on shale @ 69.3', @ 73.5 to 74.1 there is a shaley zone with slicks interwoven with angular shaped l.s. fragments well cemented together.	L0.5' RQD= 79% L0.1' RQD= 57% L0.0 RQD=82%	Box 2	
	69'					
	75'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT

HOLE NO. NX-2

EXHIBIT F-7

COST ESTIMATE

FOR

HANCOCK CREEK
AUSTIN, TEXAS

Prepared by: U. S. Army Engineer District, Forth Worth

Submitted By:

Corky P. Cobern, P.E.
Chief, Cost Engineering Branch

Recommended By:

Janis C. Murphy, Project Mgr.
Planning Division

Bobby J. Camp
Real Estate Division

Jack W. Hussey, Chief
Civil Engineering Section

Webster L. Boland
Construction Division

Approved By:

William H. Hill, P.E.
Chief, Planning Division

James P. Cain
Chief, Real Estate Division

R. Terry Coomes, P.E.
Chief, Engineering Division

Chester A. Taylor,
Chief, Construction Division

Estimate Preparation Date: 21 February 1991

Revision of Estimate: 15 November 1991

FINAL COST ESTIMATE

HANCOCK CREEK CHANNEL
AUSTIN, TEXAS

GENERAL NARRATIVE

This estimate was prepared using current guidelines and directives. All quantities of work and items of cost were developed by the appropriate parties in the Fort Worth District. Work and items of cost under each account code are discussed as considered appropriate below. The estimate was organized as required by EC 1110-2-538, Civil Works Project Cost Estimating - Code of Accounts, using the numbering system as specified in the Chart of Accounts.

ACCOUNT 01 - Lands and Damages

The costs for work and acquisitions required under this account were furnished by the Real Estate Division and based on a Gross appraisal prepared in September 1989. The reliability of information available was the reason for the 25 percent allowed for contingencies.

ACCOUNT 02 - Relocations

All parties concerned with work under this account estimated that 25 percent contingencies should be allowed for demolition and construction work required. Due to the confidence in concrete quantities, a 20 percent contingency was considered adequate. A 25 percent contingency for utility excavation and backfilling was considered appropriate due to unknown conditions.

ACCOUNT 09 - Channels and Canals

For most work under this account, 25 percent contingencies was considered an appropriate allowance because topographic maps were not available during this stage of design. Excavation and fill are major items and the risk of variance is greatest. Earthwork can be accomplished with standard dozers, rollers, etc. A contingency of 20% was used for concrete work due to the confidence in the quantities developed.

Provisions for "Care of Water" were based on the dewatering of 200 linear feet of channel with an average creek width being 8 feet within the construction boundaries. A dike could be constructed upstream and downstream of the construction site to prevent water flow into the work area. Using a flowrate of 2 miles per hour and the channel dimensions mentioned above, a daily flowrate of 874 gallons per minute was estimated for the creek. A 30-hp wheel-mounted Centrifugal pump and some aluminum piping was considered sufficient to pump the water

beyond the work area. A 10% contingency figures to be appropriate at this stage of design.

ACCOUNT 18 - Cultural Resource Preservation

Federal costs for this account were provided by the applicable elements within the Ft. Worth District.

ACCOUNT 30 - Planning, Engineering and Design

Federal costs for this account were provided by the applicable elements within the Ft. Worth District.

ACCOUNT 31 - Construction Management

Federal Costs for this account were provided by the applicable elements within the Ft. Worth District.

HANCOCK CREEK
PROJECT COST SUMMARY
FEBRUARY 1991 PRICE LEVEL
FINAL

		ESTIMATED COST	Contingencies	Total Cost
02---	RELOCATIONS			
021--	ROADS	190,342	44,908	235,250
023--	CEMETERY, UTILITIES, & STRUCTURES	195,242	48,811	244,053
09---	CHANNELS AND CANALS	3,485,856	844,658	4,330,514
18---	CULTURAL RESOURCE PRESERVATION	750	250	1,000
	TOTAL CONSTRUCTION COSTS	3,872,190	938,627	4,810,817
01---	LANDS AND DAMAGES	442,300	110,575	552,875
30---	PLANNING, ENGINEERING, & DESIGN	592,800	148,200	741,000
31---	CONSTRUCTION MANAGEMENT (S & I)	424,000	106,000	530,000
	Subtotal	1,459,100	364,775	1,823,875
	TOTAL PROJECT COST	5,331,290	1,303,402	6,634,692

FINAL INTERIM REPORT
HANCOCK CREEK, AUSTIN, TX.

COST ACCT. NO.	DESCRIPTION OF WORK	UNIT	QUANTITY	UNIT PRICE	AMOUNT	CONTINGENCY	%
01---	LAND AND DAMAGES						
01A--	Pre-authorization Planning	LS			13,000	3,250	25
01D--	Acquisition	LS			45,000	11,250	25
01D2-	Mapping, Survey, Ownerships	LS			28,000	7,000	25
01E--	Condemnation	LS			9,000	2,250	25
01F--	Appraisals	LS			42,000	10,500	25
					---	---	
	Total - Administration				137,000	34,250	
01M3-	Lands	LS			277,500	69,375	25
01M5-	Damages	LS			27,800	6,950	25
					---	---	
	Total - Lands				305,300	76,325	

	Subtotal - Lands and Damages				442,300		
	Contingencies					110,575	

01	TOTAL - LANDS AND DAMAGES				552,875		
02---	RELOCATIONS						
021--	Hancock Drive - Box Culvert						
0212-	Construct Roadbed to Subgrade						
0212C	Concrete Cl. A	CY	74.4	209.87	15,614	3,123	20
0212C	Concrete (Wingwalls)	CY	14.8	209.87	3,106	621	20
0212C	Reinforcing Steel	LBS	11,278	0.43	4,850	1,213	25
0213-	Road Surfacing						
0213B	Lime Stab. Subgrade	SY	867	2.98	2,584	646	25
0213B	Base Material	CY	174	21.00	3,654	914	25
0213B	Asphalt (MC-30)	GAL	189	1.24	234	59	25
0213B	HMAC	TON	83	29.97	2,488	622	25
021--	Houston Street - Box Culvert						
0212-	Construct Roadbed to Subgrade						
0212B	Demolish Box Culvert	LS			3,718	930	25
0212C	Concrete Cl. A	CY	141	209.87	29,592	5,918	20
0212C	Concrete (Wingwalls)	CY	25.2	209.87	5,289	1,058	20
0212B	Reinforcing Steel	LBS	20,494	0.44	9,017	2,254	25
0213-	Road Surfacing						
0213B	Lime Stab. Subgrade	SY	867	2.98	2,584	646	25
0213B	Base Material	CY	174	21.00	3,654	914	25
0213B	Asphalt (MC-30)	GAL	189	1.24	234	59	25
0213B	HMAC	TON	83	29.97	2,488	622	25
021--	North Loop Blvd						
0212-	Construct Roadbed to Subgrade						
0212B	Demolish Conc. Bridge	SF	2,000	6.15	12,300	3,075	25
0213-	Road Surfacing						
0213B	Lime Stab. Subgrade	SY	866	2.98	2,581	645	25
0213B	Base Material	CY	173	21.00	3,633	908	25
0213B	Asphalt (MC-30)	GAL	189	1.24	234	59	25
0213B	HMAC	TON	83	29.97	2,488	622	25
021L-	Bridges						
021LC	1-40' Pan Girder 50' Wide	SF	2,000	40.00	80,000	20,000	25
					---	---	
	Subtotal - Roads, Railroads, and Bridges				190,342	44,908	

FINAL INTERIM REPORT
HANCOCK CREEK, AUSTIN, TX.

COST ACCT. NO.	DESCRIPTION OF WORK	UNIT	QUANTITY	UNIT PRICE	AMOUNT	CONTINGENCY	%
023--	Cemeteries, Utilities and Structures						
0232-	Utilities - Hancock Creek						
0232B	Excavation	CY	7,318	5.00	36,590	9,148	25
0232B	Backfill	CY	6,238	1.98	12,351	3,088	25
0232B	Bedding	CY	980	15.00	14,700	3,675	25
0232B	Manholes	EA	6	3,998.72	23,992	5,998	25
0232B	8" PVC Pipe	LF	3,120	8.99	28,049	7,012	25
0232B	15" R.C.P.	LF	3,120	15.00	46,800	11,700	25
0232B	24" R.C.P.	LF	1,560	21.00	32,760	8,190	25
					---	---	
	Subtotal - Cemeteries, Utilities and Structures				195,242	48,811	
					========		
	Subtotal - Relocations				385,584		
	Contingencies					93,719	
					========		
02	TOTAL - RELOCATIONS				479,303		
09---	CHANNELS AND CANALS						
0902-	Hancock Branch						
0902B	Channels						
0902B	Care of Water	LS			67,200	6,720	10
0902B	Clearing	ACR	8.3	660.00	5,478	548	10
0902B	Grubbing	SF	6,000	0.03	180	18	10
0902B	Excavation	CY	25,600	6.01	153,856	38,464	25
0902B	Structural Excavation	CY	14,900	10.01	149,149	37,287	25
0902B	Non-expansive Fill	CY	13,200	11.02	145,464	36,366	25
0902B	6" Bedding	CY	90	33.65	3,029	757	25
0902B	18" Riprap	CY	260	39.98	10,395	2,599	25
0902B	Turfing	ACR	3.96	2,059.30	8,155	816	10
0902C	Channel Paving	CY	97	119.76	11,617	2,904	25
					---	---	
	Subtotal				554,523	126,479	
090R-	Associated General Items						
090R-	Box Culvert						
090RB	Remove Pavement	SY	930	3.50	3,255	814	25
090RB	Shoring	LF	2,700	54.41	146,907	36,727	25
090R-	U-Walls						
090RB	12" Filter Blanket	CY	3,681	23.94	88,123	22,031	25
090RB	Drill and Grout Anchor Holes	LF	16,860	20.13	339,392	84,848	25
090RB	6" PVC Pipe	LF	4,537	8.72	39,563	9,891	25
090RB	Precast Manholes	EA	20	3,425.40	68,508	17,127	25
090RB	Plaster Filter Cloth	SY	882	7.16	6,315	1,579	25
090R-	U-Walls						
090RC	Walls	CY	1,647	330.59	544,482	136,121	25
090RC	Slabs	CY	5,519	105.18	580,488	145,122	25
090RC	Protective Slab	CY	1,072	141.86	152,074	38,019	25
090R-	Box Culvert						
090RC	Concrete	CY	1,060	276.55	293,143	58,629	20
090RC	Protective Slab	CY	84	142.04	11,931	2,983	25
090RC	Reinforcing Steel	TON	753.2	872.48	657,152	164,288	25
					---	---	
	Subtotal				2,931,333	718,179	
					==========		
	Subtotal - Channels and Canals				3,485,856		
	Contingencies					844,658	
					==========		
09	TOTAL - CHANNELS AND CANALS				4,330,514		

FINAL INTERIM REPORT
HANCOCK CREEK, AUSTIN, TX.

COST ACCT. NO.	DESCRIPTION OF WORK	UNIT	QUANTITY	UNIT PRICE	AMOUNT	CONTINGENCY	%
18---	CULTURAL RESOURCE PRESERVATION						
1801-	Identification, Data Analysis Reports	LS			750	250	33
	Subtotal				750		
	Contingencies					250	
18	TOTAL - CULTURAL RESOURCE PRESERVATION				1,000		
30---	PLANNING, ENGINEERING AND DESIGN						
30A--	PLANNING	LS			8,000	2,000	25
30B--	ENGINEERING AND DESIGN						
30B8-	Value Engineering	LS			8,000	2,000	25
30B9-	E&D - Real Estate Activities - Local Cooperation - Compliance by Local Interests	LS			12,000	3,000	25
30C--	LOCAL COOPERATIVE AGREEMENT						
30C1-	Draft LCA	LS			1,200	300	25
30C2-	Final LCA and Financial Plan	LS			1,600	400	25
30C3-	LCA Negotiations	LS			1,200	300	25
30E--	DESIGN RELATED ENGINEERING						
30E1-	Subsurface Explorations	LS			8,000	2,000	25
30E2-	Sampling, Testing, and Analysis	LS			8,000	2,000	25
30E4-	Predesign Investigations	LS			80,000	20,000	25
30G--	FEATURE DESIGN MEMORANDUM						
30GY-	Draft Feature Design Memorandum	LS			195,000	48,750	25
30GY-	Final FDM	LS			29,800	7,450	25
30H--	PLANS AND SPECIFICATIONS						
30HY-	Preliminary Design	LS			140,000	35,000	25
30HY-	Final Design	LS			23,200	5,800	25
30HY-	Bidability, Constructablility and Operability Review	LS			1,600	400	25
30J--	ENGINEERING DURING CONSTRUCTION						
30J9-	All Other Engineering During Construction	LS			14,400	3,600	25
30M--	COST ENGINEERING	LS			12,800	3,200	25
30T--	PROJECT MANAGEMENT	LS			48,000	12,000	25
	Subtotal - Planning, Engineering & Design				592,800		
	Contingencies					148,200	
30	TOTAL - PLANNING, ENGINEERING AND DESIGN				741,000		

FINAL INTERIM REPORT
HANCOCK CREEK, AUSTIN, TX.

COST ACCT. NO.	DESCRIPTION OF WORK	UNIT	QUANTITY	UNIT PRICE	AMOUNT	CONTINGENCY	%
31---	CONSTRUCTION MANAGEMENT (S & I)						
31B--	Contract Administration						
31B1-	Preaward Activities	LS			2,400	600	25
31B2-	Award Activities	LS			1,600	400	25
31B3-	Review and Approval of Contract Payments	LS			4,000	1,000	25
31B4-	Contract Modifications	LS			8,000	2,000	25
31B9-	All Other Activities	LS			4,000	1,000	25
31D--	REVIEW OF SHOP DRAWINGS	LS			40,000	10,000	25
31E--	INSPECTION AND QUALITY ASSURANCE						
	Compliance Sampling and Testing	LS			40,000	10,000	25
31E9-	All Other Activities	LS			20,000	5,000	25
31F--	PROJECT OFFICE OPERATION	LS			280,000	70,000	25
31T--	PROJECT MANAGEMENT	LS			24,000	6,000	25
	Subtotal - Construction Management				424,000		
	Contingencies					106,000	
31	TOTAL - CONSTRUCTION MANAGEMENT				530,000		
	TOTAL PROJECT COSTS				6,634,692		

APPENDIX H

REAL ESTATE

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APPENDIX H

REAL ESTATE
SHOAL CREEK
AUSTIN, TEXAS

GENERAL AREA DATA

Austin, the County Seat of Travis County and the State Capital, is located in the very heart of Texas in scenic hills broken by the Colorado River. The city is approximately 162 miles northwest of Houston, 200 miles south of Dallas/Fort Worth, and 77 miles northeast of San Antonio. Almost 90 percent of the state's population is within a 300-mile radius of the city, and 70 percent is within 200 miles. The city itself has an estimated 1985 population of 445,000.

Major traffic routes include Interstate 35, U.S. Highway 183, U.S. Highway 290, and State Highways 71 and 360. In addition to the major road systems of the area, Austin is served by 11 major airlines, 4 commuter airlines, both passenger and freight rail service, several bus lines, and numerous trucking freight lines.

The city government is a council-manager form with a mayor and six city council members, each serving 2-year terms. The city of Austin owns and operates utilities (electric, water, sewer) as well as the Robert Mueller Municipal Airport, a municipal auditorium, and a regional hospital. The area has adequate city and county police and fire protection facilities and personnel to serve the population. The Austin Independent School District (AISD) is the largest of the area's public school systems, serving approximately 57,000 children in over 80 schools. In addition to the basic curriculum, the AISD offers magnet schools for all grades, a gifted and talented program, and a high technology high school known as the Science Academy of Austin. Higher education is provided by the University of Texas, St. Edwards University, Austin Community College, Maryhill College, Concordia Lutheran College, and Huston-Tillotson College.

Cultural and recreational facilities abound in this area and provide the populace with many leisure opportunities. Facilities encompass 150 parks and playgrounds covering more than 7,600 acres, 21 free swimming pools, and 10 large municipal pools, wading pools for tots, 12 community recreation centers, athletic fields, as well as senior citizen centers, golf courses, and tennis courts.

Austin has long been a center for State government, education , and tourism. In recent years, it has concentrated on diversifying its economic base further through attraction of "21st Century" industry. More than 700 manufacturing establishments are based in the Austin Metropolitan area, establishing the city as an emerging research and development, high technology center in the Southwest United States. More than 150 industries in the area are classified as high tech, encompassing about 44 percent of the total manufacturing employment. Major industries include

telecommunications, electronics, medical supplies and services, industrial chemicals, computer technology, software and peripherals, building materials, furniture, and oil field tools and equipment. Major employers, those employing 1,500 or more individuals, include the University of Texas at Austin, IBM, the city of Austin, Austin Independent School District, Motorola, Bergstrom AFB, Internal Revenue Service, Texas Instruments, Lockheed, State Department of Highways and Public Transportation, Seton Medical Center, Texas Department of Human Resources, Tracor, Texas Department of Health, Travis County, U.S. Post Office, Texas Department of Public Safety, and Advanced Micro Devices. Tourism contributes in excess of $450 million per year to the area economy and supports over 100 hotels and motels as well as contributing support to more than 1,980 restaurants and bars. Austin's cultural, educational, and historical attractions bring hundreds of thousands of visitors to the area each year. The State Capitol is a primary destination of many tourists, as is the Governor's Mansion, and the Lyndon B. Johnson Library on the campus of the University of Texas at Austin.

The city is located in the Blackland Belt soils. The principal soil characteristics of the Houston Black, Heiden, and Austin Soils are silty loams to clays. They are dark grayish brown to reddish brown in color. The bottomland soils tend toward the Tinn and Trinity clays, and are dark brown in color. The area is underlaid by cretaceous age rock, mostly limestone, which is exposed near the surface in the area. Native vegetation consists of tall bunch grasses, big/little Bluestem, Indian Grass, Sideoats Grama, and Buffalo Grass. Trees are mostly oaks, pecan, elm, bois d' arc, mesquite, lotebush, and other low woody plants. The aquifer underlying the area is in Edward-Trinity (plateau) sands, and the Trinity Group (Antler Sand). The topography is level to slightly rolling. Land to the west has some mild to steep inclines.

SUBJECT PROPERTY AND AREA

Shoal Creek, a tributary of the Colorado River is located in the west central part of Austin. The land areas involved initially begin just at the downstream side of the Missouri- Pacific Railroad bridge and north of where U.S. Highway 183 intersects the creek. This initial location begins and will consist of a 50-foot bottom channel width area and travel beneath U.S. Highway 183 where two 11-foot conduits will be bored which then continues further along with a 35- to 50- foot varying width of grass-lined channel and ends just downstream of Foster Lane.

The channelization on Hancock will begin just upstream of Houston Street where a new box culvert will be routed under a strip shopping area delivery road and tie into Hancock Creek again.

The Northwest Park tunnel intake will be located on the right bank of Shoal Creek across from Northwest Park. The outlet will be located on Lake Austin near the confluence with Bull Creek.

The 19th Street tunnel intake will be located on Shoal Creek near 19th Street and the outlet will be located just downstream of the railroad near Pressler Street.

The subject property is broken down into four separate areas as follows:

1. MOPAC to Foster Lane Channel Improvement tract.

2. Houston Street to below Hancock Drive Channel Improvement tract.

3. Northwest Park tunnel region.

4. 19th Street tunnel region.

Each of these regions have been investigated and observed. The channel areas investigated will not effectively change any of the highest and best use of the property. This use is for routing of a body of water through Shoal Creek and incorporating protection for flood control purposes. Some of these areas are owned by the city of Austin. Some have channel right-of-way easements, and some are owned by private individuals.

1. <u>CHANNEL IMPROVEMENT AREA</u>

(A) Location: <u>MOPAC TO 183</u>
Area: 2.75 acres (1,000'x 120')(Fee Acquisition)
0.92 acre (Temporary Work Area Easement)
Ownerships: One (City of Austin)
Comments: This property is currently leased to private interest. The area lies quite low and is being used as a golf driving range. The Channelization will impact the property prior to the 200-yard driving location. This area is in a flood zone restricting the use of any permanent habitable building structures. A fee estate is required for the acquisition of the necessary real estate interest along the entire length of this channelization predicated on the inclusion of a public hike/bike trail as indicated in the recreation plan.

(B) Location:<u>Under 183</u>
Area: 0.46 acre (40' x 500') (Fee Acquisition).
Ownerships: One
Comments: This property is currently an improved area with the conduits in place under Highway 183 leading to the channel. The right-of-way is assumed to stay within the current boundaries of Shoal Creek.

(C) Location: Highway 183 to Shoal Creek Boulevard
Area: 1.56 acres (80' x 850') (Fee Acquisition)
Ownerships: Three
Comments: This is a commercial/warehouse area. The right-of-way is assumed to stay within the current boundaries of Shoal Creek as it is now.

(D) Location: Shoal Creek Boulevard to Steck Avenue
Area: 6.80 Acres (3,700'x 80')(Fee Acquisition)
Ownerships: Approximately 62
Comments: This is a multifamily (apartment and duplex) area on/off Shoal Creek Boulevard. Assumptions are made that the right-of-way will stay within the current width along this line of channel improvement. Millway Drive is on the other side following the channel. This area consists of residential properties.

(E) Location: Steck Avenue to Foster Lane
Area: 7 acres (3,050' x 100')(Fee Acquisition)
1.75 acres (Temporary Work Area Easement)
Ownerships: Approximately 22
Comments: This area following the channel along Shoal Creek Boulevard is improved commercial property. In addition to the channel area, a 1.75-acre temporary construction area is proposed for access to Shoal Creek. The access will be located off the rear parking area of KVUE television station. The area following the creek opposite Shoal Creek Boulevard is mainly developed into residential with some apartment complex areas.

RECAPITULATION OF CHANNEL IMPROVEMENT AREA

TOTAL OWNERSHIPS OF CHANNEL IMPROVEMENT AREA 89
FEE ESTATES.....18.57 ACRES
TEMPORARY WORK AREA EASEMENTS.....2.67 ACRES

2. HANCOCK CHANNELIZATION

(A) Location: Houston Street to Burnet Road
Area: 1.37 acres (1,500' x 40')(Channel Improvement Easement)
Ownerships: Approximately 18
Comments: This area on both sides of the creek channel is a mixture of commercial properties and apartment complexes. The basic assumption is that the width of the channel at the top will remain the same.

(B) Location: Tunnel box under Burnet Road
Area: 0.15 acre (10′ x 675′) (10′ x 10′ box culvert)
(Channel Improvement Easement)
0.50 acre (Temporary Work Area Easement)
Ownerships: Four

(C) Location: Burnet Shopping Center area to below Hancock Drive
Area: 0.40 acre (Channel Improvement Easement)
0.20 acre (Temporary Work Area Easement)
Ownerships: Two
Comments: The path of the channel area will remain the same and widths will apparently not change.

(D) Location: Below Hancock Drive
Area: 1.18 acre (Channel Improvement Easement)
Ownerships: Two

RECAPITULATION OF HANCOCK CHANNELIZATION

TOTAL OWNERSHIPS OF HANCOCK CHANNELIZATION.....26
TEMPORARY WORK AREA EASEMENTS.....0.70 ACRE
CHANNEL IMPROVEMENT EASEMENTS.....3.10 ACRES

3. NORTHWEST PARK TUNNEL

(A) Location: Northwest Park Inlet
Area: 1.1 acres (210′ x 230′) (Fee Acquisition)
Ownerships: One
Comments: This is park property owned by the city of Austin located where Pine Crest intersects Shoal Creek Boulevard.

(B) Location: Northwest Park Outlet
Area: 1 acre (Fee Acquisition)
2 acres (Temporary Work Area Easement)
Ownerships: One
Comments:This is private ownership.

(C) Location: Pine Crest intersecting Shoal Creek to southwest to Bull Creek (FM 222)
Area: From inlet area through outlet region (Permanent Subterranean Flood Control Tunnel Easement.)
Ownerships: 34 (does not include inlet and outlet structure area)

RECAPITULATION OF NORTHWEST PARK TUNNEL AREA

TOTAL OWNERSHIPS (EXCLUDING TUNNEL).....2
FEE ESTATES.....2.1 ACRES
TEMPORARY WORK AREA EASEMENTS.....2.0 ACRES
SUBTERRANEAN FLOOD CONTROL TUNNEL OWNERSHIPS.....34

4. 19TH STREET TUNNEL AREA

(A) Location: 19th Street Tunnel Inlet (near 1800 Lamar)
Area: 0.74 acre structural area (Fee Acquisition)
0.73 acre berm area (Fee Acquisition)
1.00 acre (Temporary Work Area Easement)
Ownerships: One

(B) Location: 19th Street Tunnel Outlet (near Pressler Street)
Area: 0.50 acre structural area (Fee Acquisition)
0.50 acre (Temporary Work Area Easement)
Ownerships: One

(C) Location: 19th Street Tunnel Area Ownerships
Area: From inlet area through outlet region(Permanent Subterranean Flood Control Tunnel Easement.)
Ownerships: 26 (does not include inlet and outlet structure areas)

(D) Location: Below 19th Street Outlet (adjacent to 19th Street Outlet)
Area: 1.03 acres (Channel Improvement Easement)
Ownerships: One

RECAPITULATION OF 19TH STREET TUNNEL AREA

TOTAL OWNERSHIPS (EXCLUDING TUNNEL).....3
FEE ESTATES.....1.97 ACRES
TEMPORARY WORK AREA EASEMENTS.....1.50 ACRES
CHANNEL IMPROVEMENT EASEMENTS.....1.03 ACRES
SUBTERRANEAN FLOOD CONTROL TUNNEL OWNERSHIPS.....26

HIGHEST AND BEST USE OF THE SUBJECT PROPERTY

Highest and Best Use is defined as that reasonable and probable use that supports the highest present value as defined as of the effective date of the appraisal and that use from among reasonably probable and legal alternative uses found to be physically possible, appropriately supported, financially feasible and which results in highest value.

Land areas involved in this project consist of several different regions located in the city of Austin. These properties range in utility and zoning requirements throughout the area from industrial, commercial, multifamily, and residential usage in their present form. Based on

development trends for the general area and current observed usage, as well as practical consideration of zoning, flood plain, etc., the highest and best use of the subject property is for its current contiguous use which is mixed and varies from area to area along and involved in the channelization and tunnel areas of this proposed Shoal Creek channelization project under the description of the subject property and area.

These contiguous uses are effectively the highest and best use.

PROCESS OF VALUATION

The process of valuation usually includes three approaches to an estimate of market value. Namely, the Cost Approach, the Market Data Approach, and the Income Approach. These approaches are based upon direct and indirect comparison of market activity together with the appraiser's judgment based upon past market experience. Each of the approaches given is a separate indication of value.

The Cost Approach is based upon the cost or cash outlay to reproduce a set of improvements less appropriate allowances for all forms of depreciation plus an estimate of the land value. The Cost Approach is used as an indication of value when the property has substantial improvements located upon it.

The Market Data Approach is a direct comparison of known market transactions to the subject property. Market sales of similar property to the subject are found and confirmed by one or more of the parties involved in the transaction and compared to the property being appraised to estimate the value through the Market Approach.

The Income Approach is based upon known earnings less actual expenses to arrive at a net income. The net income is then capitalized into an indication of value by the use of an overall capitalization rate.

Once a conclusion has been reached from the approaches to value which have been used, then the different indications are correlated into a reasonable estimate to the market value of the property being appraised.

APPLICABLE APPROACH TO VALUE

Based upon the available market data, the Market Approach was used. The economic activity between 1980 and 1985 resulted in a positive real estate investment period. This was spurred on mainly by the high price of oil and consequently made availability of funds for investment. After this, a cooling off period, or transitional decline began and real estate remained fairly stable with very few properties sold or purchased. Sales from 1983 to 1988 are felt to be indicative of the market and general economy of Austin and values. The market research for unimproved properties within the subject area revealed very limited recent data.

This is primarily due and tied to the overall decline of the Texas economy as indicated.

DISPOSAL SITE ESTIMATE

Initially, a 25-acre disposal site inspection of three different locations was requested by Planning Division. This acreage amount was increased to total an amount of 45 acres at the time of initial preparation of the Gross Appraisal.

A landfill is not typical real estate. This is a short-term business enterprise that happens to be conducted on a parcel of land. Most real estate is considered to have a long useful life. With this type of property, one must consider the demand for disposal facilities and competing disposal operations in relation to the subject. Certainly there is no large demand or supply of areas in the Austin area to utilize as a comparison.

Paralleling this thought, the "value in exchange" theory is not justified. This value has a relative relationship showing comparisons with other economic goods; and since there is no demand for such, the "value in use" theory, which is subjective in nature and based on the productivity of an economic unit is more relative in theory.

Permits are issued by the city of Austin for dumping material of which most current landowners of such sites are either receptive because of the need for such fill or have an unfavorable attitude and do not need nor want any of the material. As such, the owners of landfill sites are selective of the type and amount of material. They will normally accept the fill based on individual needs at the time of contact and agreement of such. Usually at this point there is no charge for dumping; however, the owners of the property sometimes request to be the contractor for hauling this material and negotiate a price for hauling and removal from the site.

The disposal site has the potential when filled to change its character of use. This will have an affect on value, which will be enhanced by the fill dirt at no cost to the owner. The site effectively becomes more useful with more potential in all forms of physical development. Higher income potential in the form of resale also occurs due to change in the form of an open pit area to a filled, leveled area. However, the owners of the disposal site have an option to sell the fill. They in essence have no investment involved other than their time. Effectively they can produce a positive cash flow on soil given to them by the Government. This is a "no lose" situation for the owners of the potential disposal site. Another potential situation would be awarding the haul contract to an owner of the disposal site for its use. The owners receive the fill they can market at no cost and are compensated for the removal.

Developing an approach to value, the spoil site is best estimated by viewing the minimal cause and affect of utilizing land that benefits both

parties (which it does, or at least has potential for). A nominal value per acre per year was estimated to be fair and reasonable.

ESTATES

The following Standard Estates will be utilized to acquire the minimum interests in real estate to support the grant of right-of-entry for accomplishment of the construction and subsequent operation and maintenance of the project by the city of Austin.

FEE EXCEPTING AND SUBORDINATING SUBSURFACE MINERALS

The fee simple title subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines; excepting and excluding from the taking all (coal) (oil and gas) in and under said land and all appurtenant rights used in connection with the exploration, development, production, and removal of said (coal) (oil and gas), including any existing structures and improvements; provided, however, that the said (coal) (oil and gas) and appurtenant rights so excepted and excluded are hereby subordinated to the prior right of the United Stated to flood and submerge the land as may be necessary in the construction, operation, and maintenance of the project; provided further that any exploration or development of said (coal) (oil and gas) in and under said land shall be subject to Federal and State laws with respect to pollution of waters of the reservoir, and provided that the type and location of any structure, improvement, and appurtenance thereto now existing or to be erected or constructed on said land in connection with the exploration and/or development of said (coal) (oil and gas) shall be subject to the prior written approval of the District Engineer, U.S. Army Engineer District, or his duly authorized representative.

CHANNEL IMPROVEMENT EASEMENT

A perpetual and assignable right and easement to construct, operate, and maintain channel improvement works on, over and across (the land described in Schedule A) and for the purposes as authorized by the Act of Congress, including the right to clear, cut, fell, remove, and dispose of any and all timber, trees, underbrush, buildings, improvements, and/or other obstructions therefrom; to excavate, dredge, cut away, and remove any or all of said land and to place thereon dredge or spoil material; and for such other purposes as may be required in connection with said work of improvement; reserving, however, to the owners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

TEMPORARY WORK AREA EASEMENT

A temporary easement and right-of-way, in, on, over, and across (the land described in Schedule A) for a period not to exceed _____

beginning with date possession of the land is granted to the United States, for use by the United States, its representative, agents, and contractors as a (borrow area) (work area), including the right to (borrow and/or deposit fill, spoil, and waste material thereon) (move, store, and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction together with the right to trim, cut, fell, and remove therefrom all trees, underbrush, obstruction, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easement for public roads and highways, public utilities, railroads, and pipelines.

NON-STANDARD ESTATE

A water transmission tunnel easement estate was obtained from the Real Estate Section, Austin, Texas which was proposed to be utilized for acquisition of the necessary real estate interest for the project tunnels. However, the following non-standard estate for tunnel easement has recently been utilized for tunnel projects in San Antonio, Texas and is submitted for approval as a non-standard estate for the Shoal Creek project tunnels:

PERMANENT SUBTERRANEAN FLOOD CONTROL TUNNEL EASEMENT

A perpetual and assignable right and easement to construct, reconstruct, repair, operate and perpetually maintain, a subterranean flood control tunnel not to exceed_____( ) feet in diameter in, under, through and across at a depth of approximately _____ ( ) feet to ( ) feet below the surface of the ground of (the land described in Schedule A), including the right to construct the tunnel by any tunneling method, including but not limited to a rotary tunnel boring machine, road header, or any mechanical or other type mining excavator at a depth of approximately _____ feet to _____ feet below the surface of the ground and the right to dispose of all material excavated therefrom, provided however that the surface of the described area shall not be disturbed by tunnel construction, reconstruction, repair, operation and maintenance; and reserving to the landowners their heirs and assigns, all rights to utilize the surface and subsurface to a depth of _____ ('), to construct buildings or improvements so long as any excavations, drilled shafts for walls, foundation structures and similar excavations or structures do not extend to a depth of more than _____ (') feet below the surface, subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.