CLEAR FORK OF BRAZOS RIVER, ABILENE AREA, TEXAS

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED JUNE 19, 1962, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON AN INTERIM REPORT ON THE CLEAR FORK OF THE BRAZOS RIVER, ABILENE AREA, TEXAS, REQUESTED BY A RESOLUTION OF THE COMMITTEE ON PUBLIC WORKS, HOUSE OF REPRESENTATIVES, ADOPTED JULY 29, 1953

AUGUST 8, 1962.—Referred to the Committee on Public Works and ordered to be printed with two illustrations

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U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1962

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APPENDIXES ACCOMPANYING THE REPORT OF THE DISTRICT ENGINEER
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ILLUSTRATIONS ACCOMPANYING THE REPORT OF THE DISTRICT ENGINEER
(Only plates 1 and 10 printed)

LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C.

IN REPLY REFER TO:

July 31, 1962

Honorable John W. McCormack

Speaker of the House of Representatives

Dear Mr. Speaker:

I am transmitting herewith a favorable report dated 19 June 1962, from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations, on an interim report on the Clear Fork of the Brazos River, Abilene Area, Texas, requested by a resolution of the Committee on Public Works, House of Representatives, adopted 29 July 1953.

In accordance with Section 1 of Public Law 534, 78th Congress, and Public Law 85-624, the views of the Governor of Texas and the Department of Interior are set forth in the inclosed communications. The views of the Department of Commerce and the Public Health Service are inclosed also.

The Bureau of the Budget advises that there is no objection to the submission of the proposed report to the Congress; however, it states that no commitment can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation. A copy of the letter from the Bureau of the Budget is inclosed.

Sincerely yours,

Cyrus Vance

Cyrus R. Vance
Secretary of the Army

1 Incl (dup)
Rept w/accompg
papers & illus

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
BUREAU OF THE BUDGET
WASHINGTON 25, D. C.

19 July 1962

Honorable Cyrus R. Vance
Secretary of the Army
Washington 25, D. C.

Dear Mr. Secretary:

Assistant Secretary Schaub's letter of June 26, 1962, submitted the proposed interim report of the Chief of Engineers on the Clear Fork of the Brazos River, Abilene Area, Texas, requested by a resolution of the Committee on Public Works, House of Representatives, adopted July 29, 1953.

The Chief of Engineers recommends, subject to specific conditions of local cooperation, construction of channel improvements and diversions of Elm Creek and five of its tributaries in the metropolitan area of Abilene. The total cost is estimated at $38,600,000 of which $31,200,000 is Federal for construction and alteration of railroad bridges and $7,400,000 is non-Federal for lands and alterations to highways, highway bridges, and utilities. The benefit-cost ratio is stated to be 1.6.

I am authorized by the Director of the Bureau of the Budget to advise you that there would be no objection to the submission of the proposed report to the Congress. No commitment, however, can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation.

Sincerely yours,

Carl H. Schwartz, Jr.
Chief, Resources and
Civil Works Division

COMMENTS OF THE GOVERNOR OF TEXAS

EXECUTIVE DEPARTMENT
AUSTIN 11, TEXAS

PRICE DANIEL
GOVERNOR

May 7, 1962

Maj. Gen. Keith R. Barney
Acting Chief of Engineers
United States Army
Washington 25, D. C.

Dear General Barney:

This has further reference to your letter of March 15, 1962, transmitting copy of the proposed report of the Chief of Engineers on the Clear Fork of the Brazos River, Abilene Area, Texas.

At my request, the Texas Water Commission reviewed this report and approved its feasibility, as evidenced by the attached copy of a Commission Order. I concur in the findings and conclusions of the Commission.

Sincerely yours,

Price Daniel

PD:gs

Enclosure

cc: Hon. Joe D. Carter, Chairman
The Texas Water Commission
Capitol Station, Box 2311
Austin 11, Texas

TEXAS WATER COMMISSION

AN ORDER approving the feasibility of the Clear Fork of Brazos River Flood Protection - Abilene Area, Texas, Project, as proposed in the Interim Review of Reports of the Corps of Engineers, United States Army, on said Project.

BE IT ORDERED BY THE TEXAS WATER COMMISSION:

Section 1. Statement of Authority. Article 7472e, Vernon's Annotated Civil Statutes, provides that upon receipt of any engineering report submitted by a Federal Agency seeking the Governor's approval of a Federal Project, the Texas Water Commission shall study and make recommendations to the Governor as to the feasibility of the Federal Project. The Commission shall cause a public hearing to be held to receive the views of persons or groups who might be affected should the Federal Project be initiated and completed.

Section 2. Statement of Jurisdiction. (a) By letter dated March 23, 1962, the Honorable Price Daniel, Governor of Texas, requested the Texas Water Commission to study and make recommendations concerning the Interim Review of Reports of the Corps of Engineers, United States Army, on the Clear Fork of Brazos River Flood Protection - Abilene Area, Texas, Project, said Review being initially dated December 1, 1961, and to enter its order finding said Project to be feasible or not feasible. (b) In accordance with Article 7472e, the Commission caused a public hearing, after due notice by publication and mail, to be held on May 1, 1962, at 2:00 o'clock, P.M., in the offices of the Texas Water Commission, 201 East Fourteenth Street, Austin, Texas, on said Review and Project, and at which time all those interested or who may be affected should the Projected recommended in said Review be initiated and completed were requested to come forward and give testimony.

Section 3. After fully considering all the evidence and exhibits presented by persons and groups who may be affected should the Project be initiated and completed, including the matters set forth in Section 4 of

Article 7472e, the Commission finds that said Project is feasible and that the public interest will be served thereby.

Section 4. It is further ordered that a certified copy of this Order be transmitted to the Governor.

Section 5. This Order shall take effect on the 1st day of May, 1962, the date of its passage, and it is so ordered.

SIGNED IN THE PRESENCE OF THE
TEXAS WATER COMMISSION

Joe D. Carter

Joe D. Carter, Chairman

ATTEST:

Ben F. Looney, Jr., Secretary

I certify that the foregoing order was adopted by the Texas Water Commission at a meeting held on the 1st day of May, 1962, upon motion of Commissioner Dent, seconded by Commissioner Beckwith, Commissioner Dent voting "aye", Commissioner Beckwith voting "aye", and Chairman Carter voting "aye".

Ben F. Looney, Jr., Secretary

STATE OF TEXAS §

COUNTY OF TRAVIS §

I, Ben F. Looney, Jr., Secretary of the Texas Water Commission do hereby certify that the foregoing is a true and correct copy of an order of said Commission, the original of which is filed in the permanent records of said Commission.

Given under my hand and the seal of the Texas Water Commission, this the 1st day of May, A.D., 1962.

Ben F. Looney, Jr., Secretary

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

May 17, 1962

Lt. General Walter K. Wilson
Chief of Engineers
Department of the Army
Washington 25, D. C.

Dear General Wilson:

This is in reply to General Barney's letter of March 15, transmitting for our comments reports on the Clear Fork of the Brazos River, Abilene area, Texas. The reports recommend construction of channel improvements and diversions of Elm Creek and five of its tributaries for flood control in the Abilene area, at an estimated cost of $38,600,000.

No vital interests of the Department of the Interior would be affected by the proposed project. The Fish and Wildlife Service reports that the project will have insignificant effects on fish and wildlife resources. Most of the project area is urban and has no fish habitat and little wildlife habitat. During the construction of the project, there may be increased turbidity in Lake Fort Phantom Hill, but it is expected that will be reduced when bank stabilization is achieved in the new channels.

The Bureau of Mines notes that the proposed channel improvements will have no adverse effects on the mineral interests of the area and that the flood protection provided by the project would be beneficial to such industries.

The Geological Survey repeats the recommendation made by its representative at Austin, Texas, concerning the installation of an appropriate network of hydrologic stations for obtaining rainfall and streamflow records in the project area.

We appreciate the opportunity to present our views.

Sincerely yours,

John A. Carver, Jr.

Assistant Secretary of the Interior

x

COMMENTS OF THE DEPARTMENT OF COMMERCE

THE UNDER SECRETARY OF COMMERCE
FOR TRANSPORTATION
WASHINGTON 25, D. C.

April 18, 1962

Lieutenant General W. K. Wilson, Jr., USA
Chief of Engineers
Department of the Army
Washington 25, D. C.

Dear General Wilson:

As requested in General Barney's letter of March 15, 1962, I am transmitting herein the comments of the interested Department of Commerce agencies on your proposed report on the improvement of the Clear Fork of the Brazos River, Abilene area, Texas, for flood control purposes.

The Coast and Geodetic Survey advises that the primary horizontal and vertical geodetic control now existing in the area are considered adequate for the project needs. Some of the vertical control monuments along the Abilene and Southern Railroad may be endangered by construction activities. The Coast and Geodetic Survey would appreciate being notified if any of these control monuments need to be relocated.

The Bureau of Public Roads notes that the construction of the project will make it necessary that 33 highway bridges and 19 multiple box culverts be replaced or modified and that bridges be constructed at seven low water crossings. The cost of this work, $2,657,100, has been made a part of the local contribution to the project.

The Bureau of Public Roads also notes that the City of Abilene in its letter of November 30, 1961, to Colonel Paul R. West, District Engineer at Fort Worth, indicated that it would provide, without cost to the United States, all relocations of buildings, utilities, highway bridges, sewers, etc. In view of the above, it is essential that the City of Abilene be cognizant of the fact that Federal-aid highway funds cannot be used in the financing of the highway work it has promised to perform as a condition precedent to the obtaining of this Federal flood control project.

Your courtesy in providing a copy of this report for our review is appreciated.

Sincerely yours,

Frank L. Barton

Frank L. Barton
Deputy Under Secretary
for Transportation

COMMENTS OF THE PUBLIC HEALTH SERVICE

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

PUBLIC HEALTH SERVICE — WASHINGTON 25, D. C.

BUREAU OF STATE SERVICES — Refer to:

June 5, 1962

Major General Walter K. Wilson, Jr.
Chief of Engineers
Department of the Army
Washington 25, D. C.

Dear General Wilson:

This is in reply to General Barney's letter of March 15, 1962, requesting comments on the U. S. Army Engineers' Report on Clear Fork of Brazos River, Abilene Area, Texas.

The improved flood control afforded by this project should be beneficial to both general sanitation and mosquito control conditions in the area. Spoil material from channel excavation should be disposed of in such a manner as not to create mosquito producing areas.

The opportunity to review the report is appreciated. We stand ready to provide consultation concerning vector control, water supply and pollution control aspects of the projects on your request.

Sincerely yours,

Keith S. Krause

Keith S. Krause
Chief, Technical Services Branch
Division of Water Supply and
Pollution Control

CLEAR FORK OF BRAZOS RIVER, ABILENE AREA, TEXAS

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D.C.

IN REPLY REFER TO

ENGCW-PD

19 June 1962

SUBJECT: Clear Fork of Brazos River, Abilene Area, Texas

TO: THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress the interim report of the Board of Engineers for Rivers and Harbors, accompanied by the reports of the District and Division Engineers, on the Clear Fork of Brazos River, Abilene Area, Texas, in partial response to the resolution of the Committee on Public Works of the House of Representatives, United States, adopted 29 July 1953. The report considers the advisability of improvements for flood control on Elm Creek and tributaries in the metropolitan area of Abilene, Texas.

2. The District and Division Engineers recommend construction of channel improvements and diversions of Elm Creek and five of its tributaries at an estimated cost of $38,600,000. Of this, $31,200,000 would be Federal, consisting of $30,852,000 for construction and $348,000 for alterations to five railroad bridges, and $7,400,000 would be non-Federal for lands, easements, and rights-of-way and alterations to highways, highway bridges, and utilities. The benefit-cost ratio is 1.6.

3. The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. The Board recommends construction of the improvements essentially as planned by the reporting officers, subject to certain conditions of local cooperation.

4. I concur in the recommendations of the Board.

W. K. WILSON, JR.
Lieutenant General, USA
Chief of Engineers

CORPS OF ENGINEERS, U. S. ARMY
BOARD OF ENGINEERS FOR RIVERS AND HARBORS
WASHINGTON 25, D. C.

ENGBR 24 January 1962

SUBJECT: Clear Fork of Brazos River, Abilene Area, Texas

TO: Chief of Engineers
Department of the Army

1. Authority.--This report is in partial response to the following resolution adopted 29 July 1953:

> Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on the Brazos River and tributaries, Texas, submitted in House Document No. 535, 81st Congress, and prior reports, with a view to determining whether improvements for flood control and water conservation on the Clear Fork of the Brazos River and its tributaries including Catclaw Creek in the vicinity of Abilene, Texas, are advisable at this time.

It considers the advisability of improvements for flood control on Elm Creek and tributaries in the metropolitan area of Abilene, Texas. One or more reports on other areas in the Clear Fork of Brazos River basin will be submitted later under this authorization.

2. Basin description.--Elm Creek is a south-bank tributary of the Clear Fork of the Brazos River about 150 miles west of Fort Worth, Texas. It drains an area of low relief, generally sloping northeastward, consisting of 485 square miles, of which about 38 square miles are in the city of Abilene, and 335 square miles are upstream therefrom. Several tributaries drain relatively larger parts of the watershed and flow through the city. Pertinent data on the problem streams are given in the following tabulation:

Stream	Drainage area, square miles		Minimum channel capacity through city, c.f.s.
	Above mouth	Above city limits	
Elm Creek	485	155	4,000
Little Elm Creek	68	57	500
Catclaw Creek	14	7	1,500
Cedar Creek	190	42	1,600
Lytle Creek	60	49	3,000
Buttonwillow Creek	11	10	1,000

3. The city of Abilene is regarded as the focal trading point in a 16-county area in central Texas. The economy is well balanced between ranching and farming throughout most of the area, and industrial development in the Abilene area. Main activities in Abilene pertain to retailing, wholesaling, manufacturing, and educational pursuits. Population in the city was 90,368 in 1960.

4. Existing improvements.--There are no Federal projects in the Elm Creek watershed. Existing improvements by non-Federal interests consist of Lake Abilene at Elm Creek mile 53.8, Kirby Lake at Cedar Creek mile 6.2, and Lake Fort Phantom Hill at Elm Creek mile 4.3, having an aggregate capacity of 92,200 acre-feet of water-supply storage for the city of Abilene; Lytle Lake at Lytle Creek mile 1.2, with a storage capacity of 1,200 acre-feet for industrial use of the West Texas Utilities Company; and channel dams at mile 0.4 on Lytle Creek and mile 4.4 on Cedar Creek.

5. Water-resource problems.--The principal water-problem in the area consists of flooding of residential and commercial developments in the city of Abilene from storm flows on Elm, Little Elm, Catclaw, and Cedar Creeks, with Buttonwillow and Lytle Creeks contributing. Available information indicates major floods occurred in the area at least eight times in the 50-year period 1908 to 1957, inclusive. The areas subject to flooding in and adjacent to the city total 7,311 acres having property values of about $139 million. The average annual flood damages under existing conditions are estimated at $1,067,000.

6. Sufficient storage to meet the current water-supply needs in Abilene is provided by the three existing lakes in the Elm Creek watershed, as supplemented by occasional pumping from the Clear Fork. The Hubbard Creek Reservoir, presently under construction about 50 miles northeast of Abilene, will provide 273,600 acre-feet of storage for municipal and industrial uses, the greater part of which is planned for use in Abilene.

7. Improvements desired.--Local interests desire flood protection for the city of Abilene, and have suggested channel improvements and floodways on the streams through the city, reservoirs in the headwaters, diversions, and various combinations of these means. They have indicated willingness to comply with the requirements of local cooperation.

8. Improvements considered.--After considering the various plans suggested by local interests, the District Engineer reports that the most suitable plan would consist of channel improvements, together with diversion of the two most damaging streams, all providing for protection against floods having an average frequency of once in 100 years. The plan would require straightening and enlarging 36 miles of existing channel; paving 7.9 miles of the enlarged channel; clearing and snagging 5.4 miles of channel; constructing 2.3 miles of diversion dike; constructing, replacing, or modifying 33 highway bridges, 5 railroad bridges, 19 multiple-box culverts, and 7 low-water crossings; and numerous relocations of utilities and oil and gas pipelines. The District Engineer estimates the total first cost of the project, based on October 1961 prices, at $38,700,000, consisting of $30,852,000 for construction, $7,748,000 for lands, easements, rights-of-way, and relocations, and $100,000 for preauthorization studies. The annual charges are estimated at $1,369,600, including $52,000 for non-Federal maintenance. The annual benefits are estimated at $2,218,000, consisting of $1,056,000 for damages prevented to existing facilities, and $1,162,000 for damages prevented to future developments. The benefit-cost ratio is 1.6 based on a 100-year period of analysis. The District Engineer recommends construction of his plan, subject to certain conditions of local cooperation. The Division Engineer concurs.

9. Public notice.--The Division Engineer issued a public notice stating the recommendations of the reporting officers and affording interested parties an opportunity to present additional information to the Board. Careful consideration has been given to communications received.

Views and Recommendations of the Board of Engineers for Rivers and Harbors.

10. Views.--The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. The proposed local-protection works are needed and are economically justified. The requirements of local cooperation are appropriate and local interests have agreed to them.

11. Recommendations.--Accordingly, the Board recommends construction of works for flood control at and in the vicinity of Abilene, Texas, to include channel improvements, diversions, railroad bridge changes, and related works on Elm Creek and its tributaries, Little Elm Creek, Catclaw Creek, Cedar Creek, Lytle Creek, and Buttonwillow Creek, generally in accordance with the plan of the District Engineer, and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated cost to the United States of $31,200,000 for construction including railroad bridge alterations: Provided that prior to construction local interests give assurances satisfactory to the Secretary of the Army that they will, without cost to the United States:

a. Provide all lands, easements, and rights-of-way necessary for construction of the project, including designation of fill areas for disposal of spoil from channel excavation, such areas to be within a haul distance of 5 miles, or costs of excess haul distance to be borne by local interests;

b. Accomplish all relocations and alterations of buildings, utilities, pipelines, and other structures, except railroads, made necessary by the construction;

c. Hold and save the United States free from damages due to the construction works;

d. Provide assurances that encroachment on the improved channels will not be permitted;

e. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army; and

f. At least annually inform the public, and those affected, as to the location and extent of the residual flood plain areas, and that the project will not afford substantial protection from floods greater in magnitude than that which occurred on 31 July 1911.

FOR THE BOARD:

KEITH R. BARNEY
Major General, USA
Chairman

INTERIM REVIEW OF REPORTS
ON
BRAZOS RIVER AND TRIBUTARIES, TEXAS
COVERING
CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION - ABILENE AREA

S Y L L A B U S

The District Engineer finds from his investigations that a serious flood problem exists on Elm Creek and its tributaries in the urban areas of the city of Abilene. He concludes that the flood problem can be partially solved at this time by the construction of certain channel improvement works along the Elm, Little Elm, Cat Claw, Cedar, Lytle, and Buttonwillow Creeks in the Abilene area. He concludes further that there is an immediate need for the channel improvement works and that they are fully justified.

Accordingly, the District Engineer recommends the construction of the channel improvement works in the Abilene area generally as outlined in the report at an estimated construction cost to the United States of $31,200,000, subject to certain conditions of local cooperation.

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS
December 1, 1961

SUBJECT: Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area

THROUGH: Division Engineer
U. S. Army Engineer Division, Southwestern
Dallas, Texas

TO: Chief of Engineer
Department of the rmy
Washington, D. C.

INTRODUCTION

1. AUTHORITY.- This report is submitted in response to the following congressional resolution adopted July 29, 1953:

"Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requ d to review the reports on the Brazos River and tributaries, Texas, mitted in House Document No. 535, 81st Congress, and prior reports, with a view to determining whether improvements for flood control and water conservation on the Clear Fork of the Brazos River and its tributaries including Cat Claw Creek in the vicinity of Abilene, Texas, are advisable at this time."

2. Preparation of an interim report under the above-cited authorization was directed by the Chief of Engineers on October 22, 1957, as a result of requests by local interests for an immediate investigation of the flood problems in the city of Abilene, Texas.

3. SCOPE.- This report is limited to a study of the Elm Creek watershed, the tributary of the Clear Fork of the Brazos River which flows through the vicinity of Abilene. Field surveys of varying detail and appropriate office studies were made to determine the most practicable plan of improvement. The field investigations consisted of topographic surveys to establish high-water marks for the flood of 1957 and prior years where practicable, to provide profiles, channel and valley cross sections, and bridge cross sections, and to delineate the flood plains. Subsurface explorations were made to determine foundation conditions for proposed improvements, and an economic survey was made to determine the character and value of the physical property in the flood plain and the damages resulting from floods. Office studies

consisted of analyses of hydrologic, hydraulic, and economic data to develop alternate plans of improvement and to determine costs and benefits for the various plans investigated. A watershed map, a map showing the existing improvements and plans investigated, a drainage area map, and a map showing the plan of improvement considered for the Abilene area are presented on plans 1, 2, 3, 4, and 10, respectively.

4. On February 21, 1958, a public hearing was held at Abilene, Texas, at which time all interested persons were given an opportunity to present their views regarding the need of improvements for flood control and allied purposes on the Elm Creek watershed. The views expressed and data submitted at the public hearing by interested individuals, Federal and State agencies, city officials, and other interests are available for review in the Office, Chief of Engineers, Washington, D. C., and in the U. S. Army Engineer Division and District Offices at Dallas and Fort Worth, Texas, respectively. The following Federal and State governmental representatives and agencies submitted briefs or proposals for the record either before, during, or after the hearing: Honorable Omar Burleson, United States House of Representatives, sponsor of the subject legislation; Bureau of Sport Fisheries and Wildlife; Southwestern Power Administration; Bureau of Indian Affairs; U. S. Soil Conservation Service; and the Brazos River Authority of Texas. During the investigation, the District Engineer made a reconnaissance of the watershed and held conferences with local interests to discuss the proposed plan of improvement being considered and the probable requirements of local cooperation.

5. The Soil Conservation Service, United States Department of Agriculture, is authorized by the Watershed Protection and Flood Prevention Act (Public Law 566) to provide assistance in planning and installation of works of improvement for flood prevention or the conservation, development, utilization and disposal of water in creek watersheds of the basin. During the report investigations, consideration was given to the report of the Soil Conservation Service, "Upstream Flood Prevention and Water Resources Development in the Brazos River Basin," dated February 1961, prepared for the U. S. Study Commission - Texas.

6. REPORTS REVIEWED.- The congressional authorization under which this interim report is being prepared requested a review of the reports on the Brazos River and tributaries including House Document No. 535, 81st Congress, and prior reports. The reports under review did not specifically recommend or consider improvements on Elm Creek, and there are no prior reports applicable to the water problems on Elm Creek.

DESCRIPTION

7. GEOGRAPHY.- The Elm Creek watershed is located principally in Taylor County with fringe areas on the east, west, and north located in Callahan, Nolan, and Jones Counties, respectively, amounting to approximately one-seventh of the watershed area. Elm Creek, a tributary of the Clear Fork of the Brazos River, and its four tributary streams flow in a general northeasterly direction through the city of Abilene. The watershed has an overall length of about 52 miles and a maximum width of about 23 miles, and a total drainage area above Fort Phantom Hill Dam, immediately downstream of Abilene, of about 478 square miles.

8. PHYSIOGRAPHY.- The watershed area drains north into the Clear Fork of the Brazos River and lies within the southern portion of the Osage Plains section of the Central Lowland physiographic province. The Central Lowland, in turn, is a segment of the Interior Plains major physiographic division.

9. The Osage section is a plain of low relief underlain by strata gently dipping to the west-northwest. It is flanked on the south by an erosionally dissected and mature plateau which represents the Central Texas physiographic section of the Great Plains province which, also, is a component of the Interior Plains major division.

10. GEOLOGY.- Most all of the watershed of the Clear Fork, in the Abilene area, is underlain by Permian strata of the Clear Fork group. A small amount of drainage originates within outcrops of Cretaceous strata, especially in the extreme upper reaches of Lytle and Elm Creeks.

11. The general watershed area, which is underlain by Permian strata, was once covered by Cretaceous sediments which have been removed by erosional processes during post-Cretaceous times. Several vestigial and well dissected island-like outliers of Cretaceous deposits remain as isolated erosional remnants within the large area underlain by Paleozoic strata. Cretaceous rocks, represented by cap rock limestones of the Fredericksburg group immediately overlying the Trinity sand, are found in outcrops of relatively high relief approximately nine miles south of Abilene, Texas, along the upper reaches of Elm and Lytle Creeks.

12. The specific member of the Clear Fork group, which outcrops throughout the principal portion of the watershed, is the Arroyo formation consisting of shales, limestones, marls, and gypsum with the shales greatly predominating. The limestones are thin, averaging between one and three feet in thickness. Several of the more persistent limestone banks have been designated as members of the Arroyo formation, namely, the Rainey, Lytle, and Standpipe limestone, and these members appear as outcrops within the watershed area above Abilene.

13. STREAM CHARACTERISTICS.- Table 1 presents the lengths, average slopes, and existing channel capacities for streams in the Elm Creek watershed.

TABLE 1

EXISTING CHANNEL CAPACITIES, LENGTHS, AND AVERAGE SLOPES

Stream	Length (miles)	Average slope ft/mi	Location river mile From	Location river mile To	Capacity (cfs)
Elm Creek	77	7			
			11.3	14.3	8,000
			14.3	23.3	4,000
			23.3	27.7	5,000
			27.7	31.8	10,000
Little Elm Creek	26	6			
			0.0	5.7	500
			5.7	6.2	1,000
			6.2	6.7	750
Cat Claw Creek	15	11			
			0.0	7.8	1,500
Cedar Creek	33	8			
			0.0	2.4	7,000
			2.4	8.8	4,000
			8.8	11.2	2,000
			11.2	16.2	1,600
Lytle Creek	19	8			
			0.0	1.2	3,000
Buttonwillow Creek	13	13			
			0.0	4.8	1,000

14. ECONOMIC DEVELOPMENT.- The economic area studied for this report lies almost entirely within Taylor County, which is about 150 miles west of Fort Worth, Texas. The economy is well balanced between the ranching and farming throughout most of the county and the commercial and industrial development in the Abilene area. The principal farm crops grown are cotton, grain sorghums, wheat, oats, barley, peanuts, and truck crops. Livestock raised in the area include beef cattle, sheep, and goats, promoting a considerable production of wool and mohair. Other industries include the manufacture of clothing, brick and tile, concrete products, feed and cottonseed oil products, structural steel, machine shop products, and processing of foods, dairy products, meat, and soft drinks. Principal resources of the county include oil, gas, and brick clay.

15. The city of Abilene has an economic influence over about sixteen counties. It has a broad based economy composed of retail, wholesale, manufacturing, and educational activities. The petroleum industry influence is significant due to the location in Abilene of about 300 firms or branches involved in the industry. Three colleges are located in Abilene which had a total enrollment of 6,700 in 1959, as compared to 2,000 in 1945. The population of the city of Abilene was 90,368 in 1960 which is eight times its 1910 population. The population of Abilene represents 48 percent of the total population of Taylor County and the eight peripheral counties. Taylor County is the only one of these nine counties which has increased in population since 1910. Projections for the city of Abilene indicate a population of 212,000 in 2010 and 250,000 in 2060. These projections assume that adequate supplies of water will be available for those years.

16. Pertinent information concerning business in Taylor County for the years indicated are given below in 1960 constant dollars:

Income (1959)	$155,400,000
Manufacturing value (1958)	29,278,000
Wholesale sales (1958)	108,400,000
Retail sales (1958)	124,588,000

17. Retail sales for the city, in constant dollars, increased from $34,170,000 in 1929 to $124,588,000 in 1958. Wholesale sales, in constant dollars, increased from $43,000,000 in 1929 to $108,400,000 in 1958, and should continue to increase at a comparable rate in the future. Manufacturing importance is indicated due to the location of seven establishments employing 100 or more persons in the city of Abilene. Value added by manufacture (1960 dollars) shows $3,392,000 in 1929 and $29,278,000 in 1958. Data prepared by the Texas Employment Commission indicate that the total number of employees in industry groups in Taylor County increased from 16,730 in 1956 to 18,050 in 1960. Of this amount, persons employed in manufacturing increased from 2,698 in 1956 to 3,246 in 1960. Data prior to 1956 is not available. The following tabulation shows economic components by size as measured by the number of employees per establishment. Data have been extracted from "County Business Patterns, 1956" and are for four counties: Callahan, Jones, Shackelford, and Taylor, but Taylor County is by far the dominant county in this group. As noted in the tabulation, the number of retail establishments employing eight or more persons far exceeds all other economic factors. Also, there are seven establishments with 100 or more employees in retail trade.

Group	No. establishments employing 8 or more	No. establishments employing 100 or more
Mining	49	5
Construction	77	2
Manufacture	45	7
Public Utilities	36	4
Wholesale	89	1
Retail	164	7
Finance, insurance, real estate	38	1
Services	75	2

Disposable income for Taylor County, on a per capita basis, was $1,780 in 1960, or 1.83 times the 1930 income (1960 dollars). The State of Texas, on the same basis in 1960, was 1.7 times the 1930 income.

CLIMATOLOGICAL, RUNOFF, AND FLOOD DATA

18. CLIMATOLOGICAL DATA.- The climate over the Elm Creek watershed is generally mild with hot summers and cool winters. Freezing temperatures and snowfall are experienced occasionally during the movement of cold high-pressure air masses from the northwest. Climatological data, available for the first order U. S. Weather Bureau Station at Abilene, are considered representative of the Elm Creek watershed. The mean annual temperature at Abilene is 64.6 degrees Fahrenheit. Temperatures at Abilene have ranged from a maximum of 111 degrees in August 1943 to a minimum of 9 degrees below zero in January 1947. January, the coldest month, has an average minimum daily temperature of 31.4 degrees; August, the warmest month, has an average maximum daily temperature of 94.6 degrees. The prevailing wind direction is generally from the south, shifting to the south-southeast during the spring and summer months. The mean annual wind speed is about 13 miles per hour with maximum average monthly wind movements occurring in March and April. The maximum recorded wind speed was 109 miles per hour from the northwest in June 1951. The average relative humidities at midnight, 6:00 a.m., noon, and 6:00 p.m. are 66, 76, 48, and 47 percent, respectively. The average length of growing season, between killing frosts, is normally from the latter part of March to the middle of November.

19. PRECIPITATION.- The mean annual precipitation over the Elm Creek watershed is approximately 22 inches and varies from about 23 inches near the easternmost watershed boundary to about 21 inches in the headwater region. Extremes in annual precipitation on the watershed as indicated by the Abilene gage records have ranged from a maximum of 48.77 inches in 1941 to a minimum of 9.78 inches in 1956. The normal seasonal distribution of rainfall over the watershed indicates that the heaviest rainfall occurs during the period April through June. Hourly precipitation records at Abilene date back to 1905. Maximum amounts of precipitation recorded at the official Abilene station for selected durations are shown in the following tabulation:

Duration (hours)	Precipitation (inches)
1	3.47
2	4.42
3	4.53
6	6.26
12	6.56
24	6.78

20. EVAPORATION.- No evaporation records have been obtained for the Elm Creek watershed. However, the United States Study Commission - Texas, in connection with studies of the water resources of the State of Texas, has developed evaporation data for use in this watershed. The

evaporation data were based upon records at the evaporation stations at Spur, Texas, about 100 miles northwest of Abilene, and at Hords Creek Reservoir, about 50 miles south of Abilene. Evaporation data were prepared for two periods which were generally critical for reservoir storage in Texas. Average annual evaporation from a free-water surface during the period 1941-1957 was 72.43 inches.

21. RUNOFF.- There are no streamflow records available in the Elm Creek watershed, but long periods of zero flow are known to exist in all the streams. Records of daily reservoir levels and contents have been maintained since July 1940 by the U. S. Geological Survey at Lake Fort Phantom Hill on Elm Creek about 10 miles north of Abilene. Unofficial once-a-day reservoir levels since January 1950 are available at Kirby Lake on Cedar Creek just south of the city and since April 1954 at Lake Abilene on Elm Creek about 16 miles south of the city. Utilizing these data, together with estimated evaporation loss based on the data referred to in the preceding paragraph and records of water usage by the city of Abilene, runoff was estimated for the reservoirs. Records of runoff are available on the Clear Fork of Brazos River at Nugent, downstream from the mouth of Elm Creek, since February 1924. Utilizing the above data and computed rainfall-runoff relationships, monthly flows were determined by the U.S.Bureau of Reclamation for Lake Fort Phantom Hill, Kirby Lake, and Lake Abilene for the use of the U. S. Study Commission - Texas. These data were also used in this study. Monthly flows for these locations were prepared for the period 1941-1957 for those conditions of watershed development existing in 1958 and estimated to exist in 1975 and 2010 for use in water supply studies. The maximum, minimum, and average annual runoff under existing (1958) conditions for the total area above Lake Fort Phantom Hill for the 1941-1956 period were 92,800 acre-feet (1941), 6,200 acre-feet (1943), and 27,800 acre-feet respectively. Data for 1957 are incomplete but indicate 109,800 acre-feet of runoff during the January-September period (1958 conditions).

22. FLOODS.- There are no stream-gaging stations in the Elm Creek watershed. Consequently, records indicating the extent and frequency of flooding are very meager, consisting primarily of references to periods of high water taken from the files of local newspapers. No discharge measurements are available for any of the several streams in the watershed and few high water marks have been collected from floods prior to 1957. The Corps of Engineers has a program for the collection and analysis of precipitation data from the greatest storms which have occurred in the United States. An examination of data from these analyses, which date back to 1899, indicates that although the Elm Creek watershed lies within a general area of high storm rainfall, no major storm of wide areal coverage has been centered over the watershed. However, average depths of rainfall of up to about 6.5 inches over the watershed have resulted from some of the storms which have been centered near the watershed. One of the larger storms, that of

September 14-18, 1936, had 30 inches of rain in the storm center at Broome, Texas, only 50 miles southwest of Abilene, and another, that of June 19-25, 1938, had 30 inches of rain in the storm center at Eldorado, Texas, 125 miles south-southwest of Abilene. The maximum depth of precipitation for the 1936 storm over an area equivalent in size to the Elm Creek watershed was 25.7 inches in a 96-hour period, and that of the 1938 storm was 23.1 inches in 144 hours. As previously stated, no records are available of storms of this magnitude being centered over the watershed during the period 1899 to date. Although the occurrence of such storms in any event is infrequent, their absence in this area is due to chance and not to any physical barriers preventing their occurrence.

23. Although major flooding from the type of storm described above is not in evidence, the Abilene area experiences frequent flooding from the high-intensity, short-duration rainfall associated with thunderstorm activity. A large part of the rainfall occurring in the Abilene area is the result of thunderstorm activity. The Abilene area has an average of 41 days a year with thunderstorms. Flooding from thunderstorm rainfall is generally localized since the storm pattern covers comparatively small areas. That the flooding experienced in Abilene has been produced by this type of storm is evidenced by the fact that maximum high-water marks in the individual subwatersheds have been produced during widely separated flood periods. Based upon available information, serious flooding occurred one or more times in the following years: 1908, 1911, 1923, 1932, 1941, 1951, 1953, and 1957. Due to the lack of sufficient information on experienced flooding, flood frequency data used in economic evaluation were developed by the application of synthetic unit-hydrographs to rainfall data derived from the Abilene rainfall intensity-duration-frequency curves presented on plate 17.

24. HISTORICAL FLOOD DATA.- A comparison of hourly rainfall data available at the Abilene station indicates that the July 1911 storm probably would have produced a flood with higher peak discharges than any other referenced storm. Based upon the U. S. Weather Bureau rainfall intensity-duration-frequency curves for the Abilene station, the maximum one-hour rainfall of 3.47 inches (maximum for the station) on July 31, 1911, is only 0.2 inch less than the one-hour rainfall of 100-year frequency. Historical references say ". . . . the entire downtown section of Abilene was under water after a July 31, 1911, flood . . . "

FLOOD AREAS AND FLOOD DAMAGES

25. EXTENT AND CHARACTER OF FLOODED AREA.- The flood plain area consists of several extensive residential, commercial, and industrial sections including attendant urban development such as streets and utilities; several city parks including a zoo, picnicking and recreation facilities; a large number of schools and churches; civic organization buildings, including an American Legion Hall, Veterans of Foreign Wars' facilities, and a Woman's Club; a branch post office, two golf courses, one public and one private; a city water storage facility; a power plant; a stockyard; railroads and highways; and areas of agricultural land.

26. Information for analyzing the economic aspects of the flood problem was obtained through a survey which involved personal interviews with property owners, municipal officials, engineers, and residents of the area subject to flooding. Actual inspections were made of the property subject to flood damage. The flood plain areas investigated in detail for the preparation of this report consist of the areas subject to overflow along Elm, Little Elm, Cat Claw, Cedar, Buttonwillow, and Lytle Creeks in the vicinity of Abilene, Texas, by the flood of record which is a composite of the 1923, 1932, and 1957 floods, as shown on plate 10. The topography in Abilene is such that it is impossible to make a separate economic survey of each creek. In many locations flood discharges in one creek will break over into the adjacent creek basin, and the flood plains of all of the creeks lose their separate identities in the northern portions of the city. It is, therefore, necessary to consider a composite flood plain, including all the creeks, in the current economic studies. The areas investigated total 7,311 acres, all of which are urban or suburban. The total value of physical property within this area is estimated at $138,858,300, based on October 1961 prices and values. A breakdown of this property value by principal classes is given in table 2.

27. FLOOD DAMAGES.- The flood damage data obtained through the economic survey in the field formed the basis for estimating the average annual damages. These data included the floods of 1923, 1932, and 1957 which were the maximum floods of record on the various streams for which data are available. It is estimated that a recurrence of a combination of these floods under the present conditions of flood plain development would result in damages estimated at $9,344,100 as shown on table 3. Based on backwater computations and estimates of damages at various elevations of flooding, a relationship between discharge and damages was developed. By use of rainfall records, synthetic unit hydrographs, and historical flood information furnished by local interests and observed by personnel of the Fort Worth District, a relationship between peak discharge and frequency was developed. From these two relationships a damage-frequency curve, shown as curve A, plate 25, was constructed, which in turn was employed to compute the average annual damages. The average annual damages under existing conditions are computed to be $1,067,400.

TABLE 2

VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN
(October 1961 Price Level)

Item	Amount
Urban or suburban property	
Residential property	$99,395,400
Business and industrial property	18,382,500
Recreation facilities	513,000
Churches and schools	6,046,900
City property	
Parks	905,000
Streets and bridges	4,391,500
Sewage system	1,579,000
Water supply system	1,555,700
Local utilities	2,300,000
State highways	2,643,000
Railroads	253,800
County roads	70,000
U. S. Government property	175,000
Agricultural or undeveloped land	647,500
Total	$138,858,300

TABLE 3

ESTIMATED DAMAGES UNDER PRESENT STATE OF DEVELOPMENT
FROM THE FLOOD OF RECORD
(October 1961 Price Level)

Item	Amount
Urban or suburban property	
Residential property	$6,648,900
Business and industrial property	1,006,700
Recreation facilities	10,000
Churches and schools	246,000
City property	
Parks	88,000
Streets and bridges	166,600
Sewage system	187,700
Water supply system	70,500
Local utilities	128,600
State highways	14,100
Railroads	14,000
County roads	13,000
U. S. Government property	3,000
Agricultural or undeveloped land	130,700
Loss of wages	165,000
Interruption to traffic and communications	171,900
Cost of rescue work and policing	94,300
Cost of combatting insects and disease	83,800
Cost of relief and care of flood victions	101,300
Total damages	$9,344,100

TABLE 4

PERTINENT DATA

IMPROVEMENTS BY LOCAL INTERESTS

Lake Abilene	
Top of dam elevation	2,025.0
Spillway crest elevation	2,013.0
Reservoir capacity (acre-feet)	9,800
Kirby Lake	
Top of dam elevation	1,795.5
Spillway crest elevation	1,785.0
Reservoir capacity (acre-feet)	8,100
Lytle Lake	
Top of dam elevation	1,721.0
Spillway crest elevation	1,714.4
Reservoir capacity (acre-feet)	1,200
Lake Fort Phantom Hill	
Top of dam elevation	1,649.0
Spillway crest elevation	1,635.8
Reservoir capacity (acre-feet)	74,300

IMPROVEMENTS BY FEDERAL AND NON-FEDERAL AGENCIES

28. IMPROVEMENTS BY FEDERAL AGENCIES.- There are no Federal flood control structures on the Elm Creek watershed.

29. IMPROVEMENTS BY NON-FEDERAL AGENCIES.- The existing improvements constructed by non-Federal interests on the Elm Creek watershed in the vicinity of Abilene consist of four reservoirs and two channel dams on Cedar and Lytle Creeks. The reservoirs are Lake Abilene at mile 53.8 on Elm Creek, Kirby Lake at mile 6.2 on Cedar Creek, Lytle Lake at mile 1.2 on Lytle Creek, and Lake Fort Phantom Hill at mile 4.3 on Elm Creek. The channel dams are on Lytle Creek at mile 0.4 and on Cedar Creek at mile 4.4. Pertinent data for these reservoirs are presented in table 4 and locations are shown on plates 1, 2, and 3. Lake Abilene, Kirby Lake, and Lake Fort Phantom Hill reservoirs were constructed in 1921, 1927, and 1938, respectively, by the City of Abilene for water conservation purposes. Lytle Lake was constructed in 1898 by West Texas Utilities Company for industrial use.

30. IMPROVEMENTS DESIRED BY LOCAL INTERESTS.- Improvements for solution of the flood problems in this area requested by local interests at the public hearing include the following basic features or combinations thereof:

a. A flood detention reservoir on Lytle Creek east of existing Kirby Lake with an overflow diversion channel into Kirby Lake.

b. A diversion channel starting at Kirby Lake and located south and west of U. S. 83 and 84 by-pass and extending to Little Elm Creek east of Dyess Air Force Base, and rectification of Little Elm Creek channel for approximately 16,000 feet to a point 3,500 feet upstream from its confluence with Elm Creek, to intercept the flood flow from 130 square miles of drainage area on Buttonwillow Creek, Cat Claw Creek, Elm Creek, and Little Elm Creek south of the city of Abilene.

c. A floodway through the city on Lytle and Cedar Creeks from Lytle Lake and Kirby Lake to approximately 1,000 feet north of Interstate Highway 20. The floodway would have sufficient capacity to carry flood flows that cannot be intercepted by the proposed detention reservoir on Lytle Creek.

d. An alternate plan to item a above for a floodway along Cedar Creek through the city from Kirby Lake to Interstate Highway 20 which would take the anticipated flood flows from Lytle Creek in the absence of the proposed detention reservoir on Lytle Creek.

e. A floodway 1,000 to 2,000 feet wide on Elm Creek from the mouth of Indian Creek to the mouth of Cedar Creek.

f. A floodway on Little Elm Creek from a point south of Hartford Street to Elm Creek.

g. A detention dam on Elm Creek south of U. S. Highway 83 and 84 by-pass with overflow channel to Little Elm Creek at a point south of Hartford Street.

h. A detention dam on Cat Claw Creek north of the town of Wylie with overflow channel to Elm Creek.

i. Improve channel of Cat Claw Creek through the city and widen channel from North 10th Street to Elm Creek.

j. Improve channel of Cedar Creek from Kirby Lake to just north of Interstate Highway 20 with provisions for flood flow from Lytle Creek.

WATER PROBLEMS

31. GENERAL.- The water problems in the investigated areas in and adjacent to the city of Abilene consist principally of the flooding of residential and commercial developments, and adjacent agricultural areas located within the flood plain of Elm Creek and its tributaries, Cedar, Cat Claw, and Little Elm Creeks. Lytle and Buttonwillow Creeks, tributaries to Cedar Creek, also contribute to the flood problem. These problem areas are concentrated chiefly within the city limits of Abilene from the southern city limits to the headwaters of Lake Fort Phantom Hill on the north.

32. FLOOD PROBLEM.- Records of the extent and frequency of flooding in the Abilene area prior to 1957 are very few, but based upon available information, it is evident that flooding has occurred in 1908, 1911, 1923, 1932, 1941, 1951, 1953, and 1957. The 1923, 1932, and 1957 floods produced the following estimated discharges at the U. S. Highway 80 crossing:

Stream	Year	Estimated discharge (cfs)
Elm	1957	11,000
Little Elm	1932	12,100
Cat Claw	1932	11,200
Cedar	1923	18,000

The estimated 11,200 cfs on Cat Claw Creek includes overflow from Elm Creek. The nature of the topography in the Abilene area along Elm, Little Elm, and Cat Claw Creeks is such that there is no distinct line of demarcation between the flood plains of the various streams. As a result, the flood problem analysis for the problem areas has been based upon the composite flood plain for these floods even though they did not occur at the same time. Flood problem areas in the vicinity of Abilene are chiefly in the following flood plain areas:

a. Elm and Little Elm Creek from Elm Creek mile 15.3 to 31.8; Little Elm Creek from mile 0.0 to 6.7; Little Elm Creek within the Dyess Air Force Base area.

b. Cat Claw Creek from mile 0.0 to its intersection with the southern loop of U. S. Highway 83 and 84 by-pass, mile 7.7.

c. Cedar Creek from mile 0.0 to 15.8.

d. Lytle Creek from mile 0.0 to mile 1.2.

e. Buttonwillow Creek from mile 0.0 to 3.1.

Within the investigated areas the estimated value of the physical property is about $138,858,300 and the estimated average annual damages are about $1,067,400.

33. WATER SUPPLY PROBLEMS.- The existing Lake Abilene, Kirby Lake, and Lake Fort Phantom Hill, supplemented by occasional pumpage from the Clear Fork, are currently providing sufficient storage to meet the water supply needs of the project area. The Hubbard Creek Reservoir on Hubbard Creek, about 50 miles northeast of Abilene, is presently under construction. When completed, it will provide 273,600 acre-feet of storage for municipal and industrial uses, the greater portion of which will be utilized by the City of Abilene. The U. S. Study Commission - Texas report, chapter 5, Brazos River Basin, recommends construction of the Seymour Reservoir on the Brazos River, about 55 miles north-northwest of Abilene, in order to meet anticipated water demands in the Abilene area for the year 2010.

34. At the public hearing held February 21, 1958, local interests made no requests regarding water supply problems.

SOLUTIONS CONSIDERED

35. GENERAL.- The improvements considered for the solution of the flood problems of the Abilene area were: (a) channel improvement works; (b) floodway improvements, consisting of channel improvements in conjunction with levees, appurtenant interior drainage facilities, and overbank fill areas; and (c) flood control reservoirs on Lytle Creek and Elm Creek operating alone or in conjunction with channel and floodway improvements.

36. The nature of the flood problem in the Abilene area led to the consideration of several different plans. Basically, the plans considered were to provide improved channels, both with and without reservoir storage, to control as much of the contributing drainage areas as possible, and to divert the flow around the highly developed areas (Cat Claw and Elm Creeks) where possible, so that smaller improved channels in these areas would be required. The following improved channels were investigated: (a) a channel around the western perimeter of the city along the general alignment of Elm and Little Elm Creeks (including Dyess Air Force Base); (b) a channel along the alignment of Cat Claw Creek; (c) a channel along Buttonwillow, Lytle, and Cedar Creeks; and (d) a channel beginning south of Kirby Lake and terminating in the adjoining Rainy Creek watershed at a point south of the U. S. Highway 80 crossing. Flood control reservoirs were investigated at the following sites: (a) Upper Lytle Creek Reservoir at mile 6.6; (b) Mud Hill Reservoir on Elm Creek at mile 40.6; and (c) modification of Lake Abilene at Elm Creek mile 53.8. Pertinent data and cost summaries for these reservoirs are presented in table 3, appendix III.

37. PRELIMINARY STUDIES.- Preliminary design, cost, and economic studies were made of 50-year-flood frequency protection, plans A through D, to determine economic feasibility and to select the more favorable plans for further investigation. A brief description of these plans is presented in table 1, appendix III. Table 5 presents a summary of cost and economic data, and tables 2,3, and 5 in appendix III present a more detailed estimate of cost and economic data for these plans.

38. Analysis of the preliminary plans revealed that:

a. Feasible sites for flood control and/or water conservation storage upstream of the problem areas of the city of Abilene are not available. The sites selected resulted in high costs for storage and low quantity water yield.

b. A plan for standard project flood protection is not feasible.

c. Improvement at Dyess Air Force Base is not economically feasible at this time.

TABLE 5

INVESTIGATED PRELIMINARY PLANS
(1000 DOLLARS)
(October 1961 price level)
(50-year amortization period)

Plan	Costs (1) Federal	Costs (1) Non-Federal	Costs (1) Total	Annual Charges	Benefits	Benefit to Cost Ratio	Excess Benefits Over Cost
50-YEAR FLOOD FREQUENCY PROTECTION							
A - channels only	22,100.0	8,300.0	30,400.0	1,347.0	2,211.0	1.6	864.0
A - channels & upstream reservoirs (2)	35,300.0	7,800.0	43,100.0	1,924.4	2,234.9	1.2	310.5
B - channels & upstream reservoirs (3)	32,800.0	8,300.0	41,100.0	1,795.0	2,250.3	1.3	455.3
C - channels only	21,600.0	6,900.0	28,500.0	1,261.2	2,197.0	1.7	935.8
C - channels & upstream reservoirs (2)	33,800.0	6,600.0	40,400.0	1,811.5	2,220.9	1.2	409.4
D - channels & easements	23,700.0	9,100.0	32,800.0	1,529.0	2,237.6	1.5	708.6
DYESS AFB CHANNEL IMPROVEMENT							
Channel only	1,036.0	--	1,036.0	43.0	5.7	0.13	

(1) Exclusive of preauthorization costs
(2) Reservoirs at Lake Abilene and Mud Hill sites
(3) Reservoir at Upper Lytle Creek site

d. Plan C, channels only, was determined to be the most favorable plan, both from an economical and practical basis.

39. Although a plan for protection against floods of the magnitude of the standard project flood is not feasible, studies were made of the effects of the standard project flood on plan C. The study resulted in the addition of a diversion dike along the upper end of the improved channel which would divert the standard project flood from the highly developed areas along Elm and Cat Claw Creeks.

40. DETAILED INVESTIGATIONS AND STUDIES.- In order to develop a project of the proper magnitude, studies were made of plan C for protection against floods of 50-, 75-, and 100-year frequency. Cost and economic data for plan C are presented in table 6 and in table 4, appendix III.

41. Most of the potential benefits from flood control at Abilene are realized by protection from a flood of 50-year frequency. However, the size of Abilene and its rapid and continued growth, the fact that a wide area of the city is inundated during floods, and the probable life of the project being at least 100 years, all led to consideration of providing additional protection. In order to aid in choosing the proper magnitude plan, an analysis was made of economic worth of additional protection. As shown in table 6, the increase in annual benefits between plan C, 50-year protection, and plan C, 75-year protection, is $13,700, and the increase in benefits for plan C, 100-year protection, is an additional $7,300. However, preliminary estimates indicate that the increase in benefits for protection up to standard project flood is only another $7,800 annually, which, when the infrequency of occurrence of the standard project flood is considered, indicates a breakpoint on economic return at about 100-year protection. Preliminary studies also indicate that protection from floods greater than the 100-year flood would be impractical due to costly real estate and relocations and would require a rather extensive levee system which would seriously disrupt traffic patterns in the city and would increase costs disproportionately to the benefits obtained. For these reasons, plan C, 100-year protection, was adopted for the design of the plan of improvement.

42. The cost of hauling and disposing of large amounts of excess materials from the channel excavation work is an important factor in the development of the most practical plan of improvement for the Abilene area. Therefore, consideration was given to utilizing the excess materials from the channel excavation work for filling undeveloped areas.

TABLE 6

ANALYSIS OF INVESTIGATED PLAN C
(1000 DOLLARS)
(October 1961 price level)
(50-year amortization period)

Plan	Costs (1)			Annual Charges	Benefits	Benefit to Cost Ratio	Excess Benefits Over Cost
	Federal	Non-Federal	Total				
C - channels only (50-year frequency protection)	21,600.0	6,900.0	28,500.0	1,261.2	2,197.0	1.7	935.8
C - channels only (75-year frequency protection)	26,500.0	7,100.0	33,600.0	1,460.3	2,210.7	1.5	750.4
C - channels only (100-year frequency protection)	31,200.0	7,400.0	38,600.0	1,655.9	2,218.0	1.3	562.1

(1) Exclusive of preauthorization costs

43. PROPOSED PLAN OF IMPROVEMENT.- The proposed plan of improvement, which is plan C with a diversion dike, includes the following principal features and requirements:

a. The construction of about 11.6 miles of channel improvement along the general alignment of Elm and Little Elm Creeks, beginning at the southern edge of Lake Fort Phantom Hill and ending at the Dyess Air Force Base east property line on Little Elm Creek.

b. The construction of about 7.9 miles of improved channel along Cat Claw Creek (including 1.2 miles of tributary channel) from station 244+35 on the improved channel of item a to the U. S. Highway 83 and 84 by-pass on the south.

c. The construction of about 14.4 miles of improved channel along the general alignment of Cedar and Buttonwillow Creeks, beginning at the southern edge of Lake Fork Phantom Hill and extending around the southern city limits to intercept Cat Claw and Elm Creeks.

d. The construction of about 1.2 miles of improved channel along Lytle Creek from station 374+80 on the improved channel of item c to Lytle Lake Dam.

e. The construction of about 0.9 mile of improved channel along Cedar Creek from station 544+40 on the improved channel of item c to about 2,000 feet north of Kirby Lake Dam.

f. Minor cleaning and snagging of 5.4 miles of the existing Elm Creek channel between station 388+50 on the improved channel of item a to the upstream crossing of the U. S. Highway 83 and 84 by-pass on the south.

g. The construction of 2.3 miles of diversion dike located along the left bank of the proposed improved channel of item c for the protection of the Cat Claw-Elm Creek flood plains from discharges greater than the channel design.

h. The construction, replacement, and modification of 33 highway bridges, 5 railroad bridges, 19 multiple-box culverts, and 7 low water crossings.

i. The relocation and alteration of various urban utilities and of gas and oil lines of private companies.

j. The acquisition of rights-of-way, consisting of about 1,430 acres of land, for construction of the proposed channels and diversion dike.

44. The proposed plan of improvement is shown on plate 10. Pertinent data on the principal features and requirements of the proposed plan are shown in table 4, appendix IV. Profiles of the proposed channels and the diversion dike are shown on plates 11 through 16. Typical cross sections of the excavated channel and diversion dike are shown on plate 14, and a tabulation of the proposed bridge modifications is shown in table 3, appendix IV.

45. CHANNEL IMPROVEMENTS.- Channel improvements on Elm Creek would begin at the southern edge of Lake Fort Phantom Hill and extend upstream along Elm and Little Elm Creeks about 57,300 feet to the Dyess Air Force Base east property line.

46. Channel improvements on Cat Claw Creek would begin at station 244+35 on the Elm-Little Elm Creeks improved channel and extend upstream about 30,000 feet, and would divide into two channels at this point, each extending about 6,100 feet to the U. S. Highway 83 and 84 by-pass crossings. The channel would be an open rectangular concrete channel.

47. Channel improvements along Cedar and Buttonwillow Creeks would begin at station 46+70 on the Elm-Little Elm Creeks improved channel and extend about 58,100 feet upstream through the U. S. Highway 83 and 84 By-pass crossing on Buttonwillow Creek and then extend to the west about 13,400 feet to intercept Cat Claw and Elm Creeks.

48. Channel improvements on Cedar Creek would also include a channel beginning at station 544+40 of the channel described in paragraph 47 and extending about 4,900 feet to a point about 2,000 feet below Kirby Lake Dam.

49. Channel improvements on Lytle Creek would begin at station 374+80 of the channel described in paragraph 47 and extend about 6,200 feet to Lytle Lake Dam.

50. The proposed channel side slopes and bottom widths are as presented in table 7.

51. DIVERSION DIKE.- The plan of improvement would include a dike along the left bank of Elm Creek, beginning opposite station 708+00 of the proposed improved channel extension from Cedar and Buttonwillow Creeks described in paragraph 47, and ending opposite mile 36.8 on the existing Elm Creek channel. The proposed dike would be approximately 12,200 feet long, would have a minimum top width of 10 feet, and a minimum berm width of 100 feet between the toe of the dike and the top of the channel slope. Freeboard for the proposed dike would be a minimum of four feet above the water surface profile of the standard project flood.

52. GENERAL HYDROLOGY AND HYDRAULICS.- Detailed hydrologic and hydraulic design data for the plan of improvement are given in appendices I and II and on plates 17 through 24. A summary of these details

TABLE 7

PROPOSED IMPROVED CHANNEL BOTTOM WIDTHS

Item	Stations From	Stations To	Bottom Width (feet)	Side Slopes
Elm and Little Elm Creeks Improved Channel	40+00	61+50	300	1 on 2.5
	61+50	66+50	Transition	1 on 2.5
	66+50	340+00	200	1 on 2.5
	340+00	343+00	Transition	1 on 2.5
	343+00	612+63	150	1 on 2.5
Cat Claw Creek	0+00	360+50	40	Vertical
	0+00 (1)	28+50	40	Vertical
	28+50	30+00	Transition	Vertical
	30+00	61+11	20	Vertical
Cedar Creek Improved Channel and Diversion Channel	46+70	374+80	300	1 on 2.5
	374+80	377+00	Transition	1 on 2.5
	377+00	660+00	275	1 on 2.5
	660+00	670+00	Transition	1 on 2.5
	670+00	762+00	125	1 on 2.5
	0+00 (2)	8+90	125	1 on 2.5
	8+90 (2)	11+00	Transition	1 on 2.5
	11+00 (2)	49+21	100	1 on 2.5
	0+00 (3)	2+80	250	1 on 2.5
	2+80 (3)	6+40	Transition	1 on 2.5
	6+40 (3)	63+00	180	1 on 2.5

(1) Cat Claw Creek tributary channel
(2) Improved channel to Kirby Lake
(3) Improved channel to Lytle Lake

is given in paragraphs 53 through 55 while the principal physical features of the proposed plan of improvement are given in paragraphs 43 through 51.

53. DESIGN DISCHARGE CRITERIA.- The diversion channel, as well as the improved channels throughout the problem area, was designed to contain the flows produced by rainfall having a recurrence interval of 100 years. The basic rainfall intensity-duration-frequency curves for Abilene are shown on plate 17. The design storm rainfall of 7.31 inches in a 24-hour period determined from plate 17, and the resulting runoff of 5.22 inches, represent station or point rainfall of 100-year frequency and are applicable only to drainage areas of 10 square miles or less. Peak discharges produced by the 100-year point rainfall were, therefore, adjusted to reflect the reduced average depth of rainfall that normally occurs on larger areas and the adjusted discharges were adopted for channel design purposes.

54. The standard project storm for the Abilene area, centered over the area above Lake Fort Phantom Hill, would produce a uniform depth of precipitation over the watershed of 15.5 inches in 96 hours and an average depth of runoff of 10.6 inches. The standard project flood was used in establishing the grade for the dike across Elm and Cat Claw Creeks on the north side of the proposed channel which would divert Elm and Cat Claw Creek flows to the east side of the city to the Cedar Creek channel. Peak discharges produced by the standard project and the design storms at selected locations under the proposed plan of improvement are shown in the following tabulation:

Location	Drainage area (sq.mi.)	Standard Project Flood Discharges (cfs)	Design Flood Discharges (cfs)
IMPROVED CHANNELS - CEDAR, LYTLE, BUTTONWILLOW AND DIVERSION CHANNEL			
Elm Creek above diversion channel	148	74,900	37,800
Improved Cedar Creek at U.S. Hwy. 80-84	273	125,800	60,000
Improved Cedar Creek above Rainy Creek	280	126,100	60,200
Improved Cedar Creek above Elm Creek	342	151,100	78,800
IMPROVED CHANNELS - ELM, LITTLE ELM, AND CAT CLAW CREEKS			
Little Elm Creek above head of improvement	58	45,900	25,600
Little Elm Creek at U.S. Hwy. 80-84	62	46,400	26,800
Elm Creek at U.S.Hwy. 80-84	8.2	7,900	4,700
Elm Creek below Little Elm Creek	77	53,500	29,300
Cat Claw Creek at U.S.Hwy.80-84	6.5	8,900	6,300
Elm Creek below Cat Claw Creek	107	68,700	36,300
Elm Creek below Cedar Creek	456	220,800	114,800

55. WATER SURFACE PROFILES.- Backwater studies for the proposed channel improvement were based on the assumption that the flows would be confined to the improved channels, except in the downstream portions of Elm and Cedar Creeks channels, where flows were assumed to be confined to an 800-foot flow way. Under this plan, the design water surface in the improved channels would not be adversely affected by any future fills or other encroachments outside this indicated flow way. This would also permit filling of low areas outside the flow way limit with excess material from the proposed channel excavation work. Water surface profiles for the 100-year frequency design discharge and the standard project flood discharge (with downstream areas outside the flow way filled to two feet above design water surface level) were developed using a roughness coefficient of 0.030 in the Manning formula for the improved channels and 0.070 for the overbanks. The average velocities in the flow way, excluding Cat Claw Creek, would vary from 7.3 to 13.5 feet per second under design conditions. Riprap protection would be provided along the channel where necessary. Plates 11 through 16 show the water surface profiles under the proposed plan conditions, and plates 5 through 9 show the water surface profiles under existing conditions.

COSTS, CHARGES, AND BENEFITS

56. FIRST COSTS AND ANNUAL CHARGES.- The estimates of first cost and annual charges for the proposed plan of improvement for the Abilene area are summarized in table 8. The estimates are based on October 1961 price level, utilizing an amortization period of 100 years and a 5-year construction period. A detailed estimate of first cost for the proposed plan is shown in tables 1 and 2, appendix IV.

57. FLOOD CONTROL BENEFITS.- The total average annual damages in the flood plains of Elm, Little Elm, Cat Claw, Cedar, Lytle, and Buttonwillow Creeks, in the vicinity of Abilene, are estimated at $1,067,400, based on the present state of development in the flood plains and price levels of October 1961. The average annual damages for these stream limits under conditions as would be modified by the proposed plan of improvement are estimated to be $11,200 as shown on curve B, plate 25. These residual damages occur over most of the project area, and are principally losses in connection with residential property, streets, utilities, city parks, and those resulting from interruption to traffic and cost of policing activities. The resulting benefits from prevention of damages are $1,056,200. Based on trends of the past, it is logical to assume that development will continue in the flood plain even though flood protection is not provided. This probable future development has been evaluated in the economic base study shown in appendix V of this report. From paragraph 10 of appendix V, a development factor of 2.10 (for a 100-year project life) was applied to the benefits of $1,056,200, bringing the total primary benefits to $2,218,000 for prevention of damages.

58. Secondary benefits to be realized by the proposed plan of improvement have not been included in the economic justification.

59. COMPARISON OF BENEFITS AND COSTS.- The average annual benefits, the annual charges, and the ratio of benefits to charges for the proposed plan of improvement in the vicinity of Abilene, based on October 1961 price levels, are given below:

Average annual benefits	$2,218,000
Annual charges	1,369,600
Ratio of benefits to charges	1.6

TABLE 8

FIRST COST AND ANNUAL CHARGES
PROPOSED PLAN OF IMPROVEMENT
(October 1961 price level)
(in 1000 dollars)

Item	Costs
FIRST COSTS	
1. FEDERAL FIRST COST	
Railroad alterations	316.0
Channel	28,000.0
Levee	84.0
Engineering and design	1,100.0
Supervision and administration	1,700.0
Total Federal First Cost	31,200.0
2. NON-FEDERAL FIRST COST	
Lands and damages	4,500.0
Alterations to highways and utilities	2,900.0
Total non-Federal First Cost	7,400.0
3. TOTAL ESTIMATED FIRST COST OF PROJECT (1)	38,600.0
ANNUAL CHARGES	
(Construction period - 60 months) (Amortization period - 100 years) (Interest rates - Federal, 2.625% non-Federal, 5% lands, 3% other costs)	
1. FEDERAL INVESTMENT	
a. Federal first cost	31,200.0
b. Preauthorization cost	100.0
c. Interest during construction on items a & b	2,054.0
Total Federal Investment	33,354.0
2. NON-FEDERAL INVESTMENT	
a. Non-Federal first cost	7,400.0
b. Interest during construction	780.0
Total Non-Federal Investment	8,180.0
3. FEDERAL ANNUAL CHARGES	
a. Interest on Federal investment	875.5
b. Amortization of Federal investment	71.0
c. Maintenance and operation	none
Total Federal Annual Charges	946.5
4. NON-FEDERAL ANNUAL CHARGES	
a. Interest on non-Federal investment	346.6
b. Amortization of non-Federal investment	24.5
c. Maintenance and operation	52.0
Total Non-Federal Annual Charges	423.1
5. TOTAL ESTIMATED ANNUAL CHARGES	1,369.6

(1) Exclusive of preauthorization cost

LOCAL COOPERATION

60. PROPOSED LOCAL COOPERATION.- The proposed plan of improvement for the Abilene area is a local flood protection project subject to the requirements of local cooperation as generally specified for such projects. It is proposed to require local interests to participate in the project as follows:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction, maintenance, and operation of the project.

b. Provide without cost to the United States designated fill areas for the disposal of excess materials from the channel excavation work. These areas must be within reasonable haul distance of the project (approximately 5 miles) or cost for the excess haul distance must be borne by local interests.

c. Make any alterations to existing improvements, with the exception of railroads, which may be required for the construction of the project.

d. Hold and save the United States free from damages due to the construction of the project.

e. Provide assurances that encroachment on improved channels will not be permitted.

f. Agree to publicize the residual flood plain information in the community and area concerned and to provide zoning and other regulatory agencies and public information media with this information for their guidance and appropriate action.

g. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

61. Local interests, the City of Abilene, have indicated their approval of the proposed plan of improvement and have stated their willingness to be the local sponsor for the project.

62. ALLOCATION OF COSTS.- The total cost of the proposed plan of improvement is estimated at $38,600,000, of which $31,200,000 is the total Federal construction cost and $7,400,000 is the total non-Federal cost, as shown in table 8.

COORDINATION WITH OTHER AGENCIES

63. NOTICE OF INITIATION OF STUDIES.- During the initiation of studies on the Elm Creek watershed, the regional offices of other interested Federal agencies were advised of the general investigations program for 1958, by letter dated November 20, 1957. In response to the above letter, the Federal agency comments, in general, included statements of interest in the investigations program and also presented available basic and general data.

64. PUBLIC HEARING.- Participation of other agencies in the public hearing is discussed in paragraph 4.

65. BUREAU OF SPORT FISHERIES AND WILDLIFE.- The Bureau of Sport Fisheries and Wildlife in letter "report on the Brazos River and Tributaries, Clear Fork of the Brazos River, Flood Protection - Abilene Area, Taylor and Jones Counties, Texas," states that "The construction of the project may temporarily result in increased turbidity in Lake Fort Phantom Hill. This effect, however, will be alleviated when bank stabilization is achieved in the new channel. The project will have no effects upon wildlife resources."

66. SOIL CONSERVATION SERVICE.- The Soil Conservation Service stated its investigations in the area were of the reconnaissance type and that basic data had not been compiled into a report, but that such data would be available for our use.

67. REVIEW OF REPORT BY OTHER FEDERAL AGENCIES.- Copies of this report were forwarded to the interested Federal agencies at regional level for their views and comments. The agencies, in general, agreed that the project would have no adverse effect on their interests, or advised that they had no specific comments. Copies of correspondence relative to coordination with other agencies, including their formal comments and any replies thereto, are contained in appendix VI.

DISCUSSION

68. GENERAL.- This interim review of reports considers the desirability of flood control and allied improvements in the Abilene area. The report is submitted in response to the congressional resolution adopted July 29, 1953. Preparation of an interim report was directed by the Chief of Engineers on October 22, 1957.

69. GEOGRAPHY.- The city of Abilene is located in Taylor County in the Upper Brazos River Basin. Elm Creek, a tributary of the Clear Fork of the Brazos River, and four of its tributary streams flow in a general northeasterly direction through the city of Abilene. The Elm Creek watershed has an over-all length of about 52 miles, a maximum width of about 23 miles, and a total drainage area above Lake Fort Phantom Hill of about 478 square miles.

70. EXISTING IMPROVEMENTS.- The principal existing improvements in the Elm Creek watershed which are related to the water problems of the Abilene area consist of Lake Abilene, Kirby Lake, Lytle Lake, and Lake Fort Phantom Hill. These lakes were constructed by local interests for water conservation purposes.

71. FLOOD PLAIN DEVELOPMENT.- The economic investigations and studies of the limits of the subject problem areas indicate that the value of physical properties in the flood plain is about $138,858,300. The developments within the investigated flood plains of Elm, Little Elm, Cat Claw, Cedar, Lytle, and Buttonwillow Creeks consist of several extensive residential, commercial, and industrial sections with the attendant urban developments. The areas also include city parks, a zoo, a large number of schools and churches, civic and other organization buildings, two golf courses, city and county improvements, and some undeveloped land areas. It is probable that urban developments will eventually be extended into most of these undeveloped areas.

72. FLOOD AREAS AND DAMAGES.- The floods of 1923, 1932, and 1957 stressed the serious nature of the flood problems in the urban areas in the city of Abilene. The nature of the topography in the Abilene area along Elm, Little Elm, and Cat Claw Creeks is such that there is no distinct line of demarcation between the flood plains of the various streams. As a result, the flood problem analysis for the problem areas has been based upon the composite flood plain for these floods even though they did not occur at the same time. Based on an estimated value of the physical property in the flood plains, the average annual damages are estimated to be $1,067,400.

73. IMPROVEMENTS CONSIDERED.- The following improvements were considered for the Abilene area: (a) channel improvement works; (b) floodway improvements, consisting of channel improvements in conjunction with levees, appurtenant interior drainage facilities, and overbank fill areas; and (c) flood control reservoirs on Lytle and Elm Creeks, operating alone or in combination with channel and floodway improvements.

74. A plan consisting of channel and floodway improvements to provide protection against the peak discharges of the standard project flood is not feasible because the levee system would require acquisition of extensive areas of developed real estate and would seriously disrupt existing traffic patterns in the city.

75. Preliminary analysis of investigated plans to provide 50-year frequency protection revealed that: (a) reservoir storage at the investigated sites acting alone would be inadequate; (b) plans involving channel improvements in combination with reservoirs would be more costly than others considering only channel improvements; and (c) plan C, which provides for diversion of flows toward the east and down an improved Cedar Creek channel as well as improved channels along Elm, Little Elm, and Cat Claw Creeks, would be the most desirable.

76. Further detailed studies of plan C for designs to provide 75-year and 100-year flood protection revealed that 100-year frequency flood protection was economically justified. Plan C, to provide protection from 100-year frequency discharges, was selected as the basic plan of improvement.

77. Additional studies of plan C indicated that the plan could be enhanced further by the addition of a diversion dike along the upper end of the improved channel which would divert the standard project flood from the highly developed areas along Elm and Cat Claw Creeks.

78. The major features of the proposed plan consist of channel improvement works along the general alignments of Elm and Little Elm, Cat Claw, Cedar, Lytle, and Buttonwillow Creeks; and diverson of Elm and Cat Claw Creeks into the Cedar Creek improved channel by construction of a diversion channel and dike. Local interests have been advised that the disposal of the excess materials from the channel excavation work within the designated overbank fill areas prior to the construction of the planned residential and commercial developments is an important factor in the economic justification of the proposed plan of improvement.

79. U. S. SOIL CONSERVATION SERVICE.- The Soil Conservation Service, Department of Agriculture, made a reconnaissance survey of the area in 1956 and concluded that flood water retarding structures and appurtenant works were not economically feasible at that time. However, in the interest of over-all planning, any future program of the Soil Conservation Service will be ascertained during the advance planning of project improvements and due consideration of effects of existing or definitely planned structures will be given.

80. SENATE RESOLUTION 148.- Additional information on recommended and alternative projects called for by Senate Resolution 148, 85th Congress, adopted January 28, 1958, is contained in attachment to this report.

81. CONCLUSIONS.- The District Engineer concludes:

a. That a serious flood problem exists in the urban areas of the city of Abilene where extensive residential and commercial developments are subject to frequent flood damage by flood flows originating on the Elm Creek watershed.

b. That the most practical plan for the protection of the Abilene area is the construction of channel improvement works, including a diversion channel and dike, as presented in this report.

c. That the proposed project is economically justified and is urgently needed to provide protection for the flood problem area.

d. That a plan consisting of channel and floodway improvement works to provide protection against the standard project flood is not feasible.

82. RECOMMENDATIONS.- The District Engineer recommends the construction of channel improvement works in the Abilene area at an estimated total Federal construction cost of $31,200,000. The recommendation is subject to the provisions that no construction shall be undertaken until local interests have given assurances satisfactory to the Secretary of the Army that they will: (a) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction, maintenance, and operation of the project; (b) provide without cost to the United States designated fill areas for the disposal of excess materials from the channel excavation work, the areas to be within reasonable haul distance of the project (approximately 5 miles) or cost for the excess haul distance must be borne by local interests; (c) make any alterations to existing improvements, with the exception of railroads, which may be required for the construction of the project; (d) hold and save the United States free from damages due to the construction of the project; (e) provide assurances that encroachment on improved channels will not be permitted; (f) agree to publicize the residual flood plain information in the community and area concerned and to provide zoning and other regulatory agencies and public information media with this information for their guidance and appropriate action; and (g) maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

R. P. WEST
Colonel, CE
District Engineer

[First endorsement]

SWDGW-4
SUBJECT: Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area

United States Army Engineer Division, Southwestern, Dallas, Texas
December 5, 1961

TO: Chief of Engineers, Department of the Army, Washington, D.C.

I concur in the conclusions and recommendations of the District Engineer.

Robert J. Fleming Jr

ROBERT J. FLEMING, JR.
Major General, USA
Division Engineer

APPENDIX I

HYDROLOGY

CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION - ABILENE AREA

1. INTRODUCTION.- Flood protection along Elm Creek and its tributaries in the City of Abilene may be provided by: (a) channel improvement works; (b) floodway improvements, consisting of channels and levees with appurtenant interior drainage facilities and overbank fill areas; and (c) upstream flood control reservoirs, operating alone or in combination with channel and floodway improvements. Plans incorporating each of the above methods were investigated; however, the recommended plan provides principally for channel improvement, as shown on plate 10. In addition, a diversion dike will be provided across Elm and Cat Claw Creeks along the improved channel for the purpose of diverting flows in excess of the design flood around the eastern side of the city. The hydrologic design data pertinent to the recommended plan are summarized in this appendix.

2. DRAINAGE AREAS.- The Abilene project is located in Taylor County, Texas, on the Elm Creek watershed, Clear Fork of the Brazos River. The Elm Creek watershed has a total drainage area of 485 square miles, of which approximately 335 square miles are upstream of Abilene. A drainage area map of the Elm Creek watershed is shown on plate 4, and the drainage areas for selected points in the watershed are given in table 1.

3. EXISTING IMPROVEMENTS.- Existing improvements in the Elm Creek watershed consist of four reservoirs constructed by local interests: Kirby Lake, Lytle Lake, Lake Abilene, and Lake Fort Phantom Hill. These reservoirs have the following storage capacities at spillway crest: Kirby, 8100 acre-feet; Lytle 1,200 acre-feet; Abilene, 9,800 acre-feet; and Fort Phantom Hill, 74,300 acre-feet. All of the reservoirs, except Lytle Lake, are owned and operated by the city of Abilene, primarily for municipal water supply. Lytle Lake is owned and operated by the West Texas Utilities Company. Its primary use is the impoundment of water for cooling and condensing in connection with the generation of electric power. Construction was completed at Lytle Lake in 1898; at Lake Abilene in 1921; at Kirby Lake in 1927; and at Lake Fort Phantom Hill in 1938. The reservoirs are maintained at spillway crest by their owners insofar as possible (depending upon inflow, evaporation, and usage).

4. RUNOFF COEFFICIENTS AND INFILTRATION INDICES.- Runoff factors and infiltration indices were determined for the Clear Fork of the Brazos River watershed above the gage at Nugent and for the gage at Ballinger on the adjacent Elm Creek watershed in the Colorado River Basin. These studies were made in accordance with EM 1110-2-1405, "Flood Hydrograph Analyses and Computations," dated 31 August 1959.

TABLE 1

DRAINAGE AREAS

Point of Measurement	Drainage Area (sq.mi.)
Elm Creek above Lake Abilene	101
Elm Creek above Mud Hill Reservoir	137
Elm Creek above diversion channel	148
Cat Claw Creek above diversion channel	4.8
Diversion channel below Cat Claw Creek	153
Buttonwillow Creek above diversion channel	9.2
Diversion channel below Buttonwillow Creek	162
Cedar Creek above diversion channel	45
Improved Cedar Creek below Buttonwillow Creek	207
Improved Cedar Creek above Lytle Creek	213
Lytle Creek at mouth	60
Improved Cedar Creek at U. S. Hwy. 80 & 84	273
Improved Cedar Creek above Rainy Creek	280
Rainy Creek at mouth	40
Improved Cedar Creek below Rainy Creek	320
Buck Creek at mouth	21
Improved Cedar Creek at mouth	342
Little Elm Creek at head of improvement	58
Improved Little Elm Creek at U.S. Hwy. 80 & 84	62
Improved Little Elm Creek at mouth	68
Elm Creek from diversion channel to U.S.Hwy.80 & 84	8.2
Elm Creek from diversion channel to improved Little Elm Creek	8.6
Improved Elm Creek below Little Elm Creek	77
Indian Creek at mouth	16
Improved Elm Creek below Indian Creek	93
Improved Elm Creek above Cat Claw Creek	98
Cat Claw Creek from diversion channel to U. S. Hwy. 80 & 84	6.5
Cat Claw Creek from diversion channel to mouth	9.1
Improved Elm Creek below Cat Claw Creek	107
Improved Elm Creek above improved Cedar Creek	113
Improved Elm Creek below improved Cedar Creek	456
Elm Creek at Fort Phantom Hill Reservoir	478
Elm Creek at mouth	485

The computed infiltration rates for these watersheds varied from a minimum of 0.10 inch per hour to a maximum of 0.26 inch per hour while the initial loss varied from 0.83 inch to 3.00 inches. The results of these studies are presented in table 2. Similar analyses, based upon observed data, were also made in conjunction with preconstruction planning studies for the San Angelo and Hords Creek Reservoir projects, about 80 miles southwest, and 45 miles south, respectively, from the city of Abilene. As a result of the latter studies, average infiltration indices of 0.20 and 0.25 inch per hour were adopted for design purposes at the San Angelo and Hords Creek Reservoir projects, respectively. In view of the higher degree of development particularly in the lower portion of the Elm Creek watershed within the city of Abilene, it is considered that the infiltration rates used for the San Angelo and Hords Creek projects are not applicable to the Elm Creek watershed. An initial loss of 0.90 inch and an average infiltration index of 0.10 inch per hour were adopted for use with the standard project storm over the Elm Creek watershed. The adopted losses are substantially in agreement with the minimum values of initial loss and infiltration rate shown in table 2. However, in establishing the peak discharges to be used as a basis for the construction of discharge-frequency curves, the assumption was made that the losses would vary with the magnitude of the flood and that the smaller or more frequent floods would have higher infiltration rates.

5. UNIT HYDROGRAPH STUDIES.- Unit hydrograph determinations were made for selected storms for which hydrographs were available at the gage on the Clear Fork of the Brazos River at Nugent and at the Ballinger gage on the adjacent Elm Creek watershed of the Colorado River Basin. The pertinent data for these storms are shown on plates 18 and 19. Similar unit hydrograph determinations, made in conjunction with preconstruction planning studies for the San Angelo, Hords Creek, and Proctor Reservoir projects, about 80 miles southwest, 45 miles south, and 85 miles southeast, respectively, of the city of Abilene, were also available. On the basis of the latter studies, Snyder's coefficients of $C_t = 1.2$ and C_p 640 = 450 were used for design purposes at San Angelo Reservoir; $C_t = 1.0$ and C_p 640 = 600 were used at Hords Creek Reservoir; and $C_t = 2.3$ and C_p 640 = 500 were used at Proctor Reservoir.

6. SYNTHETIC UNIT HYDROGRAPHS.- In establishing coefficients to be used in Snyder's equations for the derivation of synthetic one-hour unit hydrographs for areas within the Elm Creek watershed above Abilene, consideration was given to the unit hydrograph studies referred to in the preceding paragraph and to additional unit hydrograph studies currently being made in the Colorado River Basin. The studies, on watersheds in the Brazos and Colorado River Basins at distances of about 6 to 111 miles from Abilene, showed a range in C_p 640 from about 450 to 600, with a general average of about 500. Based upon this analysis and the unit hydrograph pertinent data shown on plates 18 and 19, a C_p 640 value of 500 was adopted for the Elm Creek watershed.

TABLE 2

INFILTRATION AND RUNOFF DATA

Date of Storm	Rainfall (inches)	Runoff (inches)	Runoff (percent)	Initial loss (inches)	Infiltration index (in/hr)	Conditions preceding each storm
Clear Fork Brazos River at Nugent (drainage area = 2220 square miles)						
4-8 Sep 32	4.82	1.30	27.0	1.70	0.14	Moist; light rain 2-3 Sep, heavy rain 31 Aug-1 Sep; light rain 30 Aug.
Elm Creek (Colorado River Basin) at Ballinger (drainage area = 458 square miles)						
2-3 Sep 35	3.58	1.78	49.7	0.87	0.26	Wet; heavy rain early part 2 Sep; light rain 1 Sep; moderate rain 30 Aug.
11-12 Apr 54	3.32	1.15	34.6	0.83	0.12	Dry; no rain 26 Mar-10 Apr.
30 Apr-2 May 56	3.98	1.90	47.7	0.94	0.10	Dry; no rain 23-29 Apr; moderate rain 19-22 Apr; light rain 18 Apr.
13 Oct 57	5.39	1.81	33.6	3.00	0.15	Moist; no rain 11-12 Oct; light rain 10 Oct; moderate rain 8-9 Oct.

7. Some areas involved in the Abilene project studies are less than 10 square miles in area; therefore, synthetic one-hour unit hydrographs were used. However, all of the unit hydrograph studies referred to in paragraphs 5 and 6 above are for rainfalls of from 3- to 36-hour duration. For comparative purposes it was, therefore, necessary to convert the C_t values obtained from these studies to C_t values that would be applicable to a one-hour unit hydrograph. It was also necessary to compare the streambed slopes of each area studied with the streambed slope of Elm Creek and tributaries. Analysis of the C_t values indicated that for watersheds with approximately the same average streambed slopes as the Abilene area (19.4 feet per mile) the C_t factors derived for one-hour unit hydrographs were about 1.0. The average streambed slope for the area above Proctor Reservoir in the Brazos River Basin (where a C_t factor of 2.3 was used) was only 7.2 feet per mile, and is, therefore, not considered comparable to the Abilene area. Based upon the preceding analysis a C_t factor of 1.0 was adopted for Elm Creek and tributaries at or above Abilene.

8. The adopted coefficients (C_t = 1.0 and C_p 640 = 500) were used in Snyder's equations for the derivation of synthetic one-hour unit hydrographs. Six-hour unit hydrographs were derived from the one-hour unit hydrographs when required. The adopted synthetic one-hour unit hydrographs for the major subareas within the watershed are shown on plates 20 and 21 for natural and improved conditions. It is proposed to establish at least two stream-gaging stations within the Elm Creek watershed in the near future. It is anticipated that the data collected from these gages will be available to review adopted unit hydrograph coefficients in connection with preconstruction planning studies.

9. RAINFALL INTENSITY-FREQUENCY.- Rainfall intensity-frequency curves for durations of from one to twenty-four hours for the U. S. Weather Bureau first order station at Abilene are shown on plate 17. These curves, based on a frequency analysis developed by the U. S. Weather Bureau and presented in Technical Paper No. 25, "Rainfall Intensity-Duration-Frequency Curves," were used in the development of flood-frequency data as discussed in the following paragraph.

10. FLOOD FREQUENCY DATA.- No runoff or streamflow records are available for the Elm Creek watershed. Flood hydrographs at selected locations in the Elm Creek watershed were constructed for various frequencies by the application of unit hydrographs to rainfall data determined from the Abilene station rainfall referred to in paragraph 9. However, since station rainfall is considered applicable only to areas up to ten square miles, and the various subareas for which frequency data were required varied from less than 10 to a total of 478 square miles, a relationship was developed between peak discharges produced by point rainfall and those produced by the lesser average depths of rainfall that normally occur on larger areas. By application of this relationship to peak discharges for various frequencies developed from point rainfall, discharge-frequency curves were constructed for selected locations within the problem area for the purpose of evaluating flood damages. The modification of the discharge-frequency curves resulting

TABLE 3

STANDARD PROJECT STORM RAINFALL AND RAINFALL-EXCESS
AT CONFLUENCE OF CEDAR AND ELM CREEKS

Drainage Area = 478 Square Miles

6-hour Period	Average Rainfall (inches)	Loss (inches)	Rainfall Excess (inches)
1	0.0	0.0	0.0
2	0.1	0.1	0.0
3	0.3	0.3	0.0
4	0.1	0.1	0.0
5	0.2	0.2	0.0
6	0.3	0.3	0.0
7	1.4	0.6	0.8
8	0.2	0.2	0.0
9	0.9	0.6	0.3
10	1.8	0.6	1.2
11	8.3	0.6	7.7
12	1.2	0.6	0.6
13	0.0	0.0	0.0
14	0.1	0.1	0.0
15	0.5	0.5	0.0
16	0.1	0.1	0.0
Total	15.5	4.9	10.6

Subdivision of Maximum 6-hour Rainfall

1-hour Period	Average Rainfall (inches)	Loss (inches)	Rainfall Excess (inches)
61	0.5	0.1	0.4
62	0.6	0.1	0.5
63	1.2	0.1	1.1
64	4.6	0.1	4.5
65	0.9	0.1	0.8
66	0.5	0.1	0.4
Total	8.3	0.6	7.7

from the several investigated plans of improvement were determined in a similar manner for use in the evaluation of benefits for each plan.

11. STANDARD PROJECT STORM RAINFALL.- The standard project storm rainfall of 15.5 inches for the area upstream from Fort Phantom Hill Dam was determined in accordance with procedures described in EM 1110-2-1411 (Civil Works Engineer Bulletin No. 52-8, dated 26 March 1952). An initial loss of 0.90 inch and a uniform infiltration rate of 0.10 inch per hour were applied to the six-hour increments of the standard project storm rainfall to obtain a total of 10.6 inches of runoff. The rainfall and rainfall-excess for the standard project storm including the one-hour distribution during the maximum 6-hour period are given in table 3.

12. STANDARD PROJECT FLOOD.- Standard project flood hydrographs for each of the subareas of the Elm Creek watershed above the head of Fort Phantom Hill Reservoir were determined by application of the one-hour unit hydrographs shown on plates 20 and 21 and 6-hour unit hydrographs derived therefrom, to the rainfall-excess values given in table 3. The standard project flood discharges were then determined by routing the flood hydrographs of the contributing subareas and combining them at selected locations. The standard project flood hydrographs derived in this manner below the confluence of Elm and Cedar Creeks for natural flow and for flow through the proposed diversion channels have peak discharges of 230,600 second-feet and 220,800 second-feet, respectively, and a flood volume of 256,300 acre-feet for both natural and improved conditions. Peak discharges for the standard project flood at selected locations are shown on plate 22 for both natural and improved conditions.

13. CRITERIA FOR DESIGN.- It is considered desirable, when designing channel protection for a highly developed urban area such as the Abilene area, to provide protection against floods of the magnitude of the standard project flood. Preliminary studies, however, indicated that provision of channels of sufficient size to protect the area against the standard project flood was not feasible. Because of the nature of the plan of improvement, however, it was considered necessary to protect the highly developed areas along Elm and Cat Claw Creeks from the occurrence of floods greater than the capacity of the proposed diversion channel. For this reason a diversion dike has been provided across Elm and Cat Claw Creeks along the improved channel which will contain flows up to the standard project flood with a minimum of 4 feet of freeboard, and divert the discharge in excess of channel capacity toward and around the eastern side of the city. In view of the magnitude of the flood problem, it is considered that the adopted channel design should, as a minimum, provide protection from discharges produced by rainfall with a recurrence interval of 100 years as presented in the following paragraph.

14. DESIGN STORM RAINFALL.- The design storm rainfall of 100-year frequency was determined for durations up to 24 hours from the rainfall intensity-frequency curves of plate 17 and distributed substantially in accordance with the criteria presented on plate 10 of

EM 1110-2-1411. The rainfall and rainfall-excess for the design storm on areas of 10 square miles or less are given in table 4.

TABLE 4

DESIGN STORM RAINFALL AND RAINFALL-EXCESS

Time in hours	Rainfall (inches)	Loss (inches)	Rainfall excess (inches)	Time in hours	Rainfall (inches)	Loss (inches)	Rainfall excess (inches)
1	0.03	0.03	0.00	13	0.21	0.21	0.00
2	0.03	0.03	0.00	14	0.34	0.12	0.22
3	0.03	0.03	0.00	15	1.00	0.12	0.88
4	0.04	0.04	0.00	16	3.70	0.12	3.58
5	0.05	0.05	0.00	17	0.52	0.12	0.40
6	0.05	0.05	0.00	18	0.26	0.12	0.14
7	0.07	0.07	0.00	19	0.07	0.07	0.00
8	0.09	0.09	0.00	20	0.06	0.06	0.00
9	0.11	0.11	0.00	21	0.06	0.06	0.00
10	0.11	0.11	0.00	22	0.06	0.06	0.00
11	0.14	0.14	0.00	23	0.06	0.06	0.00
12	0.17	0.17	0.00	24	0.05	0.05	0.00
				Total	7.31	2.09	5.22

15. DESIGN FLOOD FOR CHANNELS.- A flood hydrograph for each of the incremental areas tributary to the project was obtained by applying the station or point rainfall-excess values of table 4 to the unit hydrograph for each individual area shown on plates 20 and 21. These hydrographs were routed through the channels and combined at selected locations to obtain peak discharges that would have resulted from point rainfall. The peak discharges resulting from point rainfall were then adjusted by application of the relationship referred to in paragraph 10 in order to account for the reduction in average depth of rainfall that normally occurs on larger areas. Peak discharges thus determined were adopted for the design flood throughout the project area under both natural and improved conditions and are shown on plate 22.

APPENDIX II

HYDRAULIC DESIGN

CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION - ABILENE AREA

1. GENERAL.- Studies were made to determine the hydraulic characteristics under existing conditions and for various plans of improvement on the Elm, Little Elm, Cat Claw, Buttonwillow, Cedar, and Lytle Creeks in the vicinity of Abilene, Texas.

2. WATER SURFACE PROFILES - EXISTING CONDITIONS.- Hydraulic computations were made to establish water surface profiles under existing conditions on the various creeks in the vicinity of Abilene. A rating curve was developed for the combined flow of the Lake Fort Phantom Hill spillway, which discharges into Elm Creek, and an overflow dike along the left bank, which discharges into the Clear Fork of the Brazos River. The rating curve is shown on plate 23. This rating curve was used to obtain the starting elevations for developing the water surface profiles on Elm, Little Elm, Cedar, Lytle, Buttonwillow, and Cat Claw Creeks under presently existing channel and valley conditions for discharges up to the standard project flood discharges. The water surface profiles were developed, based on Manning's formula, in accordance with paragraph 10 of EM 1110-2-1409, 7 December 1959. The mean value of the conveyances of the two end sections in each reach were used in computing the backwater curves. Roughness coefficients for use in the Manning formula were estimated to vary from 0.045 to 0.060 for the existing channel and to vary from 0.075 to 0.100 for the overbank. Plates 5 through 9 show the water surface profiles for the various discharges under existing conditions. Plate 10 shows the areas subject to flooding for these discharges. The maximum observed water surface profiles and corresponding areas subject to flooding were developed from relatively few observed high water marks and from aerial photographs taken during recent floods, as well as information obtained from long-time residents and newspaper clippings describing the historical floods.

3. EXISTING CHANNEL CAPACITIES.- Table 1 of the text shows the existing channel capacities as determined by the backwater studies correlated with observed flood flow data. The peak discharges in the various creeks for a given frequency flood were adjusted to reflect overflow from Elm Creek to Cat Claw and Little Elm upstream (south) of U. S. Highway 83 and 84 By-pass and overflow from Cat Claw Creek to Cedar Creek in the vicinity of U. S. Highway 80 during greater than bankfull flows. These adjusted discharges were used in developing the stage-frequency relationships in the various creeks under existing conditions.

4. PLAN OF IMPROVEMENT.-

a. Channels.- The proposed plan of improvement, shown on plate 10, includes channel enlargement and realignment of the existing creeks, including diversion of the Elm and Cat Claw Creeks south of the residential area to the Buttonwillow and Cedar Creek channels. The improved channel along Cedar Creek or Buttonwillow Creek would extend from the Elm and Little Elm Creeks improved channel station 46+70 in the headwaters of Lake Fort Phantom Hill to the new U. S. Highway 83 and 84 By-pass crossing on Buttonwillow Creek then extend to the west across a natural divide to intercept Cat Claw and Elm Creeks on the south. The improved channel along Elm and Little Elm Creeks would extend from improved channel station 40+00 in the headwaters of Lake Fort Phantom Hill to the east boundary of Dyess Air Force Base. The improved channels were designed to confine flows from floods having a frequency of recurrence of once in 100 years. The improved channels would be trapezoidal in shape with 1 vertical on 2.5 horizontal side slopes and channel centers depressed one foot. The channel bottom widths would vary from 20 to 300 feet. Channel width transitions would generally have an offset to transition length ratio of 1:10. Table 1 shows control grades, including improved channel sizes, bottom grades, and design water surface levels for the improved channels. Plates 11 through 16 show the proposed channel bottom grades and the computed water surface levels.

b. Cat Claw Creek channel improvement.- The proposed diversion of the discharge from the headwaters of the Elm and Cat Claw Creeks would eliminate the flooding problem along the Elm Creek. However, in order to provide protection along Cat Claw Creek from the design discharges downstream from the diversion channel, a paved open rectangular shaped channel varying in width from 20 to 40 feet would be provided. This channel would require a minimum of real estate while furnishing the required degree of protection, including scour from the high velocity flows.

c. Diversion dike.- A 12,200-foot long diversion dike, having a top width of 10 feet with 1 on 2.5 side slopes would extend along the left bank of the diversion channel and the Elm Creek from about station 715+30 on the diversion channel to about Elm Creek river mile 36.8. The dike would provide a minimum freeboard of 4 feet above the standard project flood discharge water surface. The dike profile is shown on plate 16 and a typical section of the diversion dike is shown on plate 14. Emergency control structures and/or seepage collars would be provided, as required, for all existing utility lines wherever they cross the proposed dike.

d. Dyess Air Force Base channels.- During the construction of Dyess Air Force Base (1951-1953), Little Elm Creek was improved within the limits of the base. A 100-foot bottom width ditch was designed to provide a one-foot freeboard to channel banks during the

passage of a 25-year frequency flood discharge. The ditch will pass a 50-year frequency flood discharge from off-site flows with minimum overflow. The Air Force Base runway and aprons were designed for 2-year protection and the cantonment area, including runway area overflow, for 10-year protection. Any further channel improvement, while reducing the effect of off-site flows through the base, would not eliminate flooding in the airfield and cantonment areas from greater than design local flows.

e. Channel scour protection.- Based on preliminary soils investigation, riprap, varying from 12 to 18 inches, would be provided along the improved channel banks where necessary. The riprap (on 6-inch bedding material) would extend to a point one foot above the design water surface. Plate 24 shows the basis for the size of riprap selected.

5. WATER SURFACE PROFILES - IMPROVED CONDITIONS.- Backwater studies for the proposed channel improvement were based on the assumption that the flows would be confined to the improved channels, except in the downstream portions of the Elm and Cedar Creeks channels, where flows were assumed to be confined to an 800-foot flow way. Under this plan, the design water surface in the improved channels would not be adversely affected by any future levees, fills, or other encroachments outside the indicated flow way. This would also permit filling of low areas outside this flow way limit with excess material from the proposed channel excavation work. Water surface profiles for the 100-year frequency design discharge and the standard project flood discharge (with downstream areas outside the flow way filled to two feet above design water surface) were developed using a roughness coefficient of 0.030 in the Manning formula for the improved channels and 0.070 for the overbanks. The average velocities in the flow way, excluding Cat Claw Creek, would vary from 7.3 to 13.5 feet per second under design conditions. Table 1 and plates 11 through 16 show the water surface levels under design conditions.

6. BRIDGE IMPROVEMENTS.- Table 3, appendix IV, shows low steel elevations and bridge modifications that would be required in connection with the channel improvement work. All bridges would extend across the entire improved channel and would provide a minimum clearance of 3 feet between low steel elevation and design water surface.

TABLE 1

HYDRAULIC DESIGN CONTROL GRADES
CHANNEL IMPROVEMENT - ABILENE, TEXAS

Location	Approx. Channel Station (feet)	Improved Channel Grade (ft-msl)	Improved Channel Bottom Width (feet)	Design Discharge (cfs)	Design Water Surface (ft-msl)	Average Channel Velocity (fps)
			Lytle Creek Tributary Channel Improvement			
374+80 Cedar Creek Improved Channel	0+00	1675.3	300/250	60,000	1689.5	13.2
Change channel size & grade	2+50	1675.8	250/180	27,000	1689.9	7.0
East So. 5th St.	20+00	1678.8	180	27,000	1692.5	9.8
Camron Dam	23+00	1679.2	180	27,000	1693.0	9.6
Near Lytle Spillway (P.O.T.)	51+20	1684.1	180	27,000	1697.5	10.0
			Kirby Lake Tributary Channel Improvement			
544+40 Cedar Creek Improved Channel	0+00	1722.7	275/125	48,400	1735.3	13.2
Change channel size & grade	8+79	1725.5	125/100	17,300	1737.1	10.4
County Road L.W.C.	35+30	1734.9	100	17,300	1746.4	12.6
End channel	49+21	1739.7	100	17,300	1751.3	12.4
			Cat Claw Creek Improved Channel			
244+35 Elm & Little Elm Creeks Imp.Channel	0+00	1655.0	200/40	36,300	1668.5	12.1
Grade Change	50+00	1671.0	40	6,400	1679.3	19.4
P.O.T. Ambler St.	95+57	1682.8	40	6,400	1691.7	18.2
P.O.T. State St.	156+00	1698.6	40	6,400	1707.4	18.3
P.O.T. Hwy. 80	192+00	1707.9	40	6,300	1716.7	18.0
Grade Change	200+00	1710.0	40	5,600	1718.6	16.4
P.O.T. So. 9th St.	242+50	1719.4	40	4,720	1727.3	14.9
Grade Change	280+00	1727.6	40	4,200	1734.9	14.3
Grade Change	300+00	1732.5	40	2,800	1739.2	10.6
U.S. Hwy. 83 By-pass	360+49	1751.0	40	2,000	1755.0	12.7
			Tributary Channel to Cat Claw Creek			
301+30 Cat Claw Creek Improved Channel	0+00	1732.9	40/40	2,800	1739.4	10.8
Change channel size & grade	28+50	1735.0	40/20	870	1739.8	4.5
U.S. Hwy. 83 By-pass	61+11	1750.0	20	540	1752.5	10.8
			Elm and Little Elm Creeks Improved Channel			
Begin Channel Improvement	40+00	1620.6	300	114,800	1647.4	8.4
Confluence Cedar Creek	64+00	1622.0	300/200	114,800	1650.2	7.3
P.O.T. County Rd.	125+20	1632.7	200	36,600	1651.5	7.5
P.O.T. Abilene & Northern Ry.	167+50	1640.1	200	36,600	1655.8	10.3
P.O.T. U.S. Hwy. 83	191+70	1644.3	200	36,600	1659.5	10.7
Cat Claw Creek	252+50	1655.0	200	34,200	1669.8	10.3
U.S. Hwy. 83	292+00	1661.9	200	34,200	1676.3	10.5
Change channel size & grade Indian Cr.	340+00	1670.3	200/150	29,300	1684.6	9.2
Change in grade	370+00	1675.6	150	29,300	1690.5	10.9
Elm Creek	382+77	1677.8	150	27,300	1692.8	10.2
U.S. Hwy. 80 (So. Lane)	485+50	1694.7	150	26,800	1709.4	10.4
Change in Q (start Little Elm) 544+30 = (-34+20)	544+30	1704.5	150/100	25,600	1719.0	10.0
Hwy.	35+60	1722.0	100	25,600	1737.2	12.7
			Cedar Creek Improved Channel and Diversion Channel			
Begin Improvement Channel (Elm Cr.)	40+00	1620.6	300	114,800	1647.4	8.4
Confluence - East & West Channel (Begin East Channel)	64+00	1622.0	300	114,800	1650.2	7.3
Grade Change	112+00	1625.0	300	78,800	1651.6	8.3
Buck Creek	120+00	1626.4	300	72,300	1652.2	5.5
Rainy Creek	146+50	1630.8	300	60,200	1653.5	7.7
Interstate Hwy. No. 20	218+50	1643.0	300	60,200	1659.4	11.0
College Ave.	307+80	1658.0	300	60,200	1673.9	11.7
No. 7th St.	348+00	1668.4	300	60,200	1682.7	13.1
U.S. Hwy. No. 80	368+70	1673.8	300	60,000	1687.8	13.3
T&P Ry. - Begin Transition	374+80	1675.3	300	60,000	1689.5	13.2
End Transition	380+00	1676.7	275	48,400	1690.7	11.7
So. 7th St.	402+00	1682.3	275	48,400	1695.8	12.2
So. 25th St. - Grade Change	487+00	1704.2	275	48,400	1717.4	12.6
Buttonwillow Creek	546+50	1723.4	275	48,400	1735.7	13.6
U.S. Hwys. 83 & 84	605+80	1742.5	275	38,800	1753.3	12.6
Begin Diversion & Grade Change	626+32	1749.0	275	38,800	1759.9	12.5
Begin Transition	650+00	1750.8	275	38,100	1764.4	9.5
Grade Change	660+00	1751.5	175	38,100	1765.7	13.5
End Transition	670+00	1752.4	125	38,100	1768.6	14.9
Cat Claw Creek	720+00	1756.5	125	38,100	177.4	10.6
End Imp. Channel (Elm Creek)	762+00	1760.0	125	37,800	1782.5	9.7

APPENDIX III

FORMULATION OF THE PLAN OF IMPROVEMENT

CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION - ABILENE AREA

1. GENERAL.- This report considers various plans for the control of floods at and in the vicinity of Abilene, Texas. During the course of the study, consideration was also given to water supply problems.

2. WATER PROBLEMS.- The water problems in the Abilene area consist principally of the flooding of residential, commercial development, and agricultural areas located in the flood plain of Elm Creek and its tributaries. The major part of the damages caused by floods occurs in the highly developed areas along Elm, Cat Claw, Cedar, and Lytle Creeks in the city of Abilene. Analysis of the flood problem in the Abilene area is extremely difficult because there have been no stream discharge measurements made and few high water marks have been observed. In addition, the topography in the area is such that in some reaches no distinct flood plain exists between the various creeks. However, flooding is known to have occurred in 1908, 1911, 1923, 1932, 1941, 1951, 1953, and 1957.

3. From its confluence with the Clear Fork of the Brazos River to the Abilene and Northern Railway crossing at mile 15.3, the principal improvements on Elm Creek include Lake Fork Phantom Hill and its surrounding developments. From river mile 15.3 to the confluence of Little Elm Creek at river mile 23.2 the improvements vary from rural to urban. The improvements in this reach of Elm Creek include a residential section, major highway crossings, and the Elm Oak Country Club and golf course. The largest concentration of improvements along Elm Creek occurs between mile 23.2 and mile 31.8. This area encompasses a major residential and commercial section of the city of Abilene, and along with the Little Elm Creek and Cat Claw Creek area discussed in paragraph 5, represents the major flood problem area for the western portion of the city. The developments in this reach vary from moderate to highly expensive residences, including the attendant churches, schools, shopping centers, and businesses. Commercial developments in this reach are concentrated chiefly in the vicinity of the U.S.Highway 80 crossing at mile 26.8. The bankfull capacity of Elm Creek between mile 23.2 and 27.7 and between 27.7 and 31.8 is about 5,000 and 10,000 cfs, respectively. Once the bankfull capacity of the stream is exceeded in the lower end of this reach, there is an interchange of flow between Elm, Little Elm, and Cat Claw Creeks such that no distinct line of demarcation exists between the flood plains. Between mile 15.3 and mile 31.8 Elm Creek has seven highway bridges, one railroad bridge, 4 county or street bridges, and many utility line crossings.

4. From its confluence with Elm Creek to the U. S. Highway 80 crossing at mile 2.6, the flood plain of Little Elm Creek is presently undeveloped. The bankfull capacity of the creek in this reach is about 500 cfs. Above U. S. Highway 80 crossing to the Dyess Air Force Base property line at mile 6.7, the area contains commercial properties, a trailer park, and a drive-in theater. The Little Elm Creek channel above the U. S. Highway 80 crossing is more defined, the bankfull capacity increasing to about 1,000 cfs. The investigated Little Elm Creek flood plain north of Dyess Air Force Base contains one major highway bridge crossing, one major railroad, and 3 county or street bridges. Flood problems within the limits of Dyess Air Force Base include those caused by the restriction of flow because of the inadequate downstream capacity of Little Elm Creek downstream from the Base, and the potential flooding of the runway by overflow from Little Elm Creek and its tributaries upstream of the Base.

5. The Cat Claw Creek flood plain is highly developed in the city of Abilene, and the value of the improvements in this flood problem area varies from inexpensive to expensive residential and commercial developments. The existing channel capacity of Cat Claw is about 1,500 cfs. As stated in paragraph 3, there is no distinct line of demarcation between Cat Claw, Elm,and Little Elm Creeks flood plains in the lower reaches, and there is evidence of some interchange of flows south of U. S. Highway 80. The improvements along Cat Claw Creek are extremely close to the banks of the stream such that damage occurs even with very small amounts of flooding.

6. The flood plain improvements in the Cedar Creek and tributary areas vary from rural to urban, but are not quite as extensive as those of Elm, Little Elm, and Cat Claw. From the southern edge of Lake Fort Phantom Hill to College Drive crossing at mile 7.3, the improvements are mostly rural. The bankfull capacity of Cedar Creek is about 4,000 cfs between miles 2.4 and 8.8. The major flood problem area of Cedar and Lytle Creeks is in the next reach, from mile 7.3 to 25th Street crossing at mile 11.8 on Cedar Creek, and from mile 0.00 to mile 1.2 on Lytle Creek. The improvements include residential properties, power and utility company plants, public parks, cemeteries, schools, and other improvements. The existing Lytle Lake reservoir, at mile 1.2, is owned by the West Texas Utilities Company. The area around the lake contains a few relatively expensive homes. The bankfull capacity of Cedar Creek between mile 7.3 and mile 11.8 is about 2,000 cfs, and Lytle Creek, below the existing reservoir, has a bankfull capacity of about 3,000 cfs.

7. From mile 11.8 on Cedar Creek to the southern city limits, the flood plain area includes Cedar and Buttonwillow Creeks. The meandering course of the two streams is such that no line of demarcation exists between the two flood plains. Improvements in the Cedar Creek flood plain from mile 11.8 to Kirby Lake, and in the Buttonwillow Creek flood plain from Cedar Creek to mile 3.1 include the Abilene

Country Club, a municipal golf course, a boys' ranch, and residential improvements. The investigated flood plains of Cedar, Lytle, and Buttonwillow Creeks contain 6 major highway bridges, two railroad bridges,and 9 county or city street crossings.

8. WATER SUPPLY PROBLEMS.- The city of Abilene is presently being supplied by the existing Abilene system of reservoirs, consisting of Lake Abilene, Kirby Lake, and Lake Fort Phantom Hill. Local interests made no specific requests at the public hearing in regard to water supply.

9. The anticipated water requirements for the Abilene area, as presented in the U. S. Study Commission - Texas report, chapter 5, Brazos River Basin, by year 1975 is 34.5 mgd. To meet this need, the City is planning to obtain water from the Hubbard Creek Reservoir presently under construction.

10. The U. S. Study Commission water requirements for the Abilene area by year 2010 is 63.4 mgd. Alternate source of supply must be found, since studies made in connection with the U. S. Study Commission-Texas have shown that it cannot be developed from Elm Creek in the vicinity of Abilene. The most probable source of supply would be Seymour Reservoir on the Brazos River, which is being considered in long range planning.

11. SOLUTIONS CONSIDERED.- As stated in paragraph 35 of the text of this report, the improvements considered for the solution of the flood problems of the Abilene area were: (a) channel improvement works; (b) floodway improvements, consisting of channel improvements in conjunction with levees, appurtenant interior drainage facilities, and overbank fill areas; and (c) flood control reservoirs on Lytle and Elm Creeks, operating alone or in combination with channel and floodway improvements. A brief description of the various investigated plans is presented in table 1.

12. The development of the investigated plans for the Abilene area was based in general upon the composite requests by local interests, presented at and subsequent to the public hearing described in paragraph 4 of the text.

13. Reservoir storage was investigated at the following sites: (a) Upper Lytle Creek Reservoir at mile 6.6; (b) Mud Hill Reservoir at Elm Creek mile 40.6; and (c) modification of Lake Abilene at Elm Creek mile 53.8.

14. Improved channel investigations included; (a) a channel around the western perimeter of the city along the general alignment of Elm and Little Elm Creeks (including the Dyess Air Force Base area); (b) a channel along the alignment of Cat Claw Creek; (c) a channel along Buttonwillow, Lytle, and Cedar Creeks; and (d) a channel

beginning south of Kirby Lake and terminating in the adjoining Rainy Creek watershed at a point south of the U. S. Highway 80 crossing.

15. INVESTIGATED RESERVOIRS.- The reservoir sites which were selected for study are approximately the same as those suggested by local interests. These sites were investigated in the preliminary studies to determine if there was adequate storage capacity available; if they would reduce flood flows; and if they were economically feasible. Construction costs for the Upper Lytle Creek site, mile 6.6, and the Mud Hill site, Elm Creek mile 40.6, would be extremely high because of the long embankments and because the sites do not possess good spillway location sites. Based on investigated flood control storages of 20,400 and 15,600 acre-feet at the Upper Lytle Creek and Mud Hill sites, the cost per acre-foot of storage would be $313 and $475, respectively. Investigations of the possible modification of Lake Abilene, Elm Creek mile 53.8, to provide 41,300 acre-feet of flood control storage indicate that the cost of storage would be about $186 per acre-foot and the reservoir would have to be dedicated to flood control purposes to obtain flood control storage at that cost. Cost for flood control storage in excess of about $100 per acre-foot is seldom justified even when providing a high degree of protection. These reservoirs would reduce the peak flow on the respective creeks materially at the points of proposed diversion, but due to distribution of flow in the various creeks the effect of the reservoirs is much less at U. S. Highway 80. Since the reduction in peak flow does not result in material reduction in cost of channels and since storage space is not available for more than 50-year flood frequencies in Mud Hill and Upper Lytle Creek Reservoirs, no further consideration was given to flood control by reservoirs.

16. The reservoir sites were then investigated for use as possible water supply reservoirs. Using flows developed by the U. S. Study Commission - Texas, as described in paragraph 33 of the text, it was concluded that the yield from Elm Creek could not be increased significantly over that now produced by Lake Abilene, Kirby Lake, and Lake Fort Phantom Hill. The additional yield would be in the nature of 0.6 mgd. As shown in paragraphs 9 and 10, the 1975 water supply requirement of 34.5 mgd will be met by the Hubbard Creek Reservoir, now under construction. The requirement of an additional 28.9 mgd by year 2010 could not be materially aided by the small contribution from additional Elm Creek reservoirs.

17. STANDARD PROJECT FLOOD PROTECTION.- Because of the flood hazard of the Abilene area and in view of the size of the urban area subject to flooding, consideration was given to possible provisions for protection against the standard project flood. Analysis of the investigated reservoir sites revealed that:

a. Topographic limitations preclude storage of flood volumes of the magnitude of the standard project flood in the Upper Lytle Creek and Mud Hill sites.

b. The geographic location of Lake Abilene with respect to the problem areas is such that it would not have an appreciable effect on flood reductions, acting alone or in combination with local floodway improvements.

c. The storage of flood volumes to the limits of the available topography in Upper Lytle and Mud Hill sites would not appreciably reduce the size of downstream channel or floodway works.

18. Analysis of local channel improvements and floodway plans A through D to provide protection against the standard project flood indicated that:

a. Larger channels would be impractical due to costly real estate and relocations.

b. Plans A, B, and D could be modified by the addition of levees, but such a system would be so extensive as to be impractical.

c. Plan C, with the addition of levees, was found to be possible, but such addition would seriously disrupt traffic patterns in the city and would add to local interests' costs to such an extent that they would probably be beyond the financial capabilities of Abilene.

d. It was found, however, that some measure of protection against the standard project flood could be obtained by construction of a diversion dike in conjunction with plan C. The dike would prevent overflow along Elm and Cat Claw Creeks and would divert the flow to the Cedar Creek channel where the resultant damage would be the least.

19. FACTORS INFLUENCING THE SELECTION OF THE PLAN OF IMPROVEMENT.- As discussed in paragraphs 11 through 18 above, various solutions to the water problems at Abilene were considered. Based on those studies, it was concluded that plan C would best solve those problems. In order to arrive at the proper magnitude for the project, plan C was investigated for additional degrees of protection. Results of studies for 50-, 75-, and 100-year flood frequency protection are shown in table 4.

20. In view of the flood problem, the size of the urban area, and the probable life of the proposed plan, the 100-year frequency discharges were adopted for the channel design. The plan of improvement will provide a high degree of protection for the problem areas and will incidently relieve some of the flood problem at Dyess Air Force Base.

21. EFFECT OF THE PLAN OF IMPROVEMENT ON EXISTING IMPROVEMENTS.- Analysis of the performance characteristics of the proposed plan of improvement included consideration of its effects upon the existing improvements in the area, and in particular, Lake Fort Phantom Hill. The proposed plan would not have any adverse effect upon this reservoir.

TABLE 1

DESCRIPTION OF INVESTIGATED PRELIMINARY PLANS

Plan	Description
A (Channels only)	a. Improved channel of 62,600± linear feet along the general alignment of Cedar and Buttonwillow Creeks extending from Lake Fort Phantom Hill on the north to the Buttonwillow Creek crossing at Highway 83 and 84 By-pass on the south b. Improved channel on Lytle Creek consisting of 6,400± linear feet and extending from the improved channel on Cedar Creek to Lytle Creek Dam. c. Improved channel of 4,700± linear feet along the general alignment of Cedar Creek extending from the intersection of the new alignment of Buttonwillow Creek in item a to 2,000± feet below Kirby Lake Dam. d. Improved channel of 70,000± linear feet along general alignment of Elm and Little Elm Creeks extending from improved channel in item a near intersection of Cedar and Elm Creeks on the north to the Cat Claw crossing at Curry Lane on the south. e. Improved channel of 42,300± linear feet along the general alignment of Cat Claw Creek extending from its intersection with improved channel in item d on the north to its crossing at Highway 83 and 84 By-pass on the south. f. Improved channel of 7,000± linear feet along the general alignment of Little Elm Creek extending from its intersection of the improved channel in item d on the north to the east boundary of Dyess Air Force Base on the south. g. Minor cleaning and snagging of existing Elm Creek channel from its intersection with improved channel in item d on the north to its crossing of Highway 83 and 84 By-pass on the south.
A (Channels and reservoirs)	a. Same as items a, b, and c in plan A (channels only). b. Enlarge Lake Abilene to provide 41,300 acre-feet of flood control storage. c. Construct Mud Hill Reservoir to provide 15,600 acre-feet of flood control storage. d. Same as item d in plan A (channels only) except channel will be reduced in width. e. Same as in items e, f, and g in plan A (channels only).
B (Channels and reservoirs)	a. Construct Lytle Creek Reservoir to provide 20,400 acre-feet of flood control storage. b. Improved channel of 56,800± linear feet along the general alignment of Cedar and Buttonwillow Creeks extending from Lake Fort Fort Phantom Hill on the north to 5,800± feet east of the ButtonwillowCreek crossing at U. S. Highway 83 and 84 By-pass on the south. c. Same as item b in plan A (channels only) except the channel will be reduced in width. d. Same as item c in plan A (channels only) except the channel will be reduced in width. e. Improved channel of 86,000± linear feet extending from the intersection of Cedar Creek improved channel in item b on the north along the general alignment of Elm and Little Elm Creeks after reaching the south side cutting across Elm, Cat Claw, and Buttonwillow Creeks to Kirby Lake. f. Same as item e in plan A (channels only). g. Same as item f in plan A (channels only). h. Same as item g in plan A (channels only).
C (Channels only)	a. Improved channel of 77,400± linear feet along the general alignment of Cedar and Buttonwillow Creeks extending from Lake Fort Phantom Hill on the north to Elm Creek on the south, 6,500± feet upstream from its Curry Lane crossing. b. Improved channel on Lytle Creek consisting of 6,400± linear feet and extending from the improved channel on Cedar Creek to Lytle Creek Dam. c. Improved channel of 4,700± linear feet along the general alignment of Cedar Creek extending from the intersection of the new alignment of Buttonwillow Creek in item a to 2,000± feet below Kirby Lake Dam. d. Improved channel of 61,400± linear feet along the general alignment of Elm and Little Elm Creeks extending from the improved channel in item a near the intersection of Cedar and Elm Creeks on the north to the east boundary of Dyess Air Force Base on Little Elm Creek on the west. e. Improved channel of 42,300± linear feet along the general alignment of Cat Claw Creek extending from its intersection with improved channel in item d on the north to its crossing at Highway 83 and 84 By-pass on the south. f. Minor cleaning and snagging of existing Elm Creek channel from its intersection with improved channel in item d on the north to its crossing at Highway 83 and 84 By-pass on the south.
C (Channels and reservoirs)	a. Same as item a in plan C (channels only) except channel will be reduced in width. b. Same as items b and c in plan C (channels only). c. Enlarge Lake Abilene to provide 41,300 acre-feet of flood control storage. d. Construct Mud Hill Reservoir to provide 15,600 acre-feet of flood control storage. e. Same as items d, e, and f in plan C (channels only).
D (Channels and easements)	a. Same as item b in plan B except the channel will be increased in width from Lake Fort Phantom Hill to the intersection of Rainy Creek. b. Improved channel of 36,000± linear feet extending in a northeasterly direction from about Kirby Lake to Rainy Creek east of Abilene Municipal Airport with flowage easements on Rainy Creek. c. Same as item b in plan C (channels only) except the channel will be reduced in width. d. Same as item c in plan C (channels only) except the channel will be reduced in width. e. Same as item d in plan A (channels only). f. Same as item e in plan C (channels only). g. Same as item f in plan A (channels only). h. Same as item f in plan C (channels only).
Dyess Air Force Base (channel)	a. Improved channel of 7,300± linear feet along the general alignment of Little Elm Creek extending from the south boundary of Dyess Air Force Base to approximately 2,300 feet west of the Little Elm crossing of Farm-Market Road 707.

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TABLE 2

INVESTIGATED PRELIMINARY PLANS
(in 1000 dollars)
(October 1961 price level)

Item	Plan A (Channels only plan)	Plan A (Channels and reservoirs) Improved Channels	Plan A (Channels and reservoirs) Reservoirs (1)	Plan A (Channels and reservoirs) Total	Plan B (Channels and reservoir) Improved Channels	Plan B (Channels and reservoir) Reservoir (2)	Plan B (Channels and reservoir) Total	Plan C (Channels only plan)	Plan C (Channels and reservoirs) Improved Channels	Plan C (Channels and reservoirs) Reservoirs (1)	Plan C (Channels and reservoirs) Total	Plan D (Channels and easements)
FIRST COSTS												
1. FEDERAL FIRST COST												
Lands and damages	--	--	1,037.0	1,037.0	--	720.0	720.0	--	--	1,037.0	1,037.0	--
Relocations	--	--	325.0	325.0	--	130.0	130.0	--	--	325.0	325.0	--
Railroad alterations	215.0	194.0	--	194.0	214.0	--	214.0	200.0	177.0	--	177.0	131.0
Dam	--	--	12,200.0	12,200.0	--	4,880.0	4,880.0	--	--	12,200.0	12,200.0	--
a. Embankment	--	--	(4,399.0)	(4,399.0)	--	(2,310.0)	(2,310.0)	--	--	(4,399.0)	(4,399.0)	--
b. Slope protection	--	--	(34.0)	(34.0)	--	(20.0)	(20.0)	--	--	(34.0)	(34.0)	--
c. Spillway	--	--	(7,660.0	(7,660.0)	--	(2,550.0)	(2,550.0)	--	--	(7,660.0)	(7,660.0)	--
d. Outlet works	--	--	(107.0)	(107.0)	--	--	--	--	--	(107.0)	(107.0)	--
Channel	19,800.0	18,200.0	--	18,200.0	23,700.0	--	23,700.0	19,400.0	16,800.0	--	16,800.0	20,700.0
Access road	--	--	40.0	40.0	--	20.0	20.0	--	--	40.0	40.0	--
Levee	96.0	96.0	--	96.0	84.0	--	84.0	84.0	84.0	--	84.0	--
Buildings and grounds	--	--	240.0	240.0	--	120.0	120.0	--	--	240.0	240.0	--
Operating equipment	--	--	50.0	50.0	--	25.0	25.0	--	--	50.0	50.0	--
Engineering and design	779.0	650.0	474.0	1,124.0	952.0	205.0	1,157.0	716.0	639.0	474.0	1,113.0	856.0
Supervision and administration	1,210.0	1,060.0	734.0	1,794.0	1,450.0	300.0	1,750.0	1,200.0	1,000.0	734.0	1,794.0	1,300.0
Total Federal first cost	22,100.0	20,200.0	15,100.0	35,300.0	26,400.0	6,400.0	32,800.0	21,600.0	18,700.0	15,100.0	33,800.0	23,700.0
2. NON-FEDERAL FIRST COST												
Lands and damages	4,800.0	4,600.0	--	4,600.0	4,600.0	--	4,600.0	4,400.0	4,300.0	--	4,300.0	5,500.0
Alterations to highways and utilities	3,500.0	3,200.0	--	3,200.0	3,700.0	--	3,700.0	2,500.0	2,300.0	--	2,300.0	3,600.0
Total non-Federal first cost	8,300.0	7,800.0	--	7,800.0	8,300.0	--	8,300.0	6,900.0	6,600.0	--	6,600.0	9,100.0
3. TOTAL ESTIMATED FIRST COST OF PROJECT (3)	30,400.0	28,000.0	15,100.0	43,100.0	34,700.0	6,400.0	41,100.0	28,500.0	25,300.0	15,100.0	40,400.0	32,800.0
ANNUAL CHARGES												
(Construction period - 60 months) (Amortization period - 50 years) (Interest rates - Federal, 2.625%; non-Federal, 5% lands, 3% other costs)												
1. FEDERAL INVESTMENT												
a. Federal first cost	22,100.0	20,200.0	15,100.0	35,300.0	26,400.0	6,400.0	32,800.0	21,600.0	18,700.0	15,100.0	33,800.0	23,700.0
b. Preauthorization costs	100.0	90.0	10.0	100.0	95.0	5.0	100.0	100.0	90.0	10.0	100.0	100.0
c. Interest during construction	1,457.0	1,332.0	992.0	2,324.0	1,739.0	420.0	2,159.0	1,424.0	1,233.0	992.0	2,225.0	1,562.0
Total Federal investment	23,657.0	21,622.0	16,102.0	37,724.0	28,234.0	6,825.0	35,059.0	23,124.0	20,023.0	16,102.0	36,125.0	25,362.0
2. NON-FEDERAL INVESTMENT												
a. Non-Federal first cost	8,300.0	7,800.0	--	7,800.0	8,300.0	--	8,300.0	6,900.0	6,600.0	--	6,600.0	9,100.0
b. Interest during construction	862.5	815.0	--	815.0	852.5	--	852.5	737.5	710.0	--	710.0	957.0
Total non-Federal investment	9,162.5	8,615.0	--	8,615.0	9,152.5	--	9,152.5	7,637.5	7,310.0	--	7,310.0	10,057.0
3. FEDERAL ANNUAL CHARGES												
a. Interest on Federal investment	621.0	567.6	422.6	990.0	741.1	179.2	920.3	607.0	525.6	422.6	948.2	665.8
b. Amortization of Federal investment	234.0	213.8	159.2	373.0	279.2	67.5	346.7	228.7	198.0	159.2	357.2	250.8
c. Maintenance and operation	--	--	95.0	95.0	--	40.0	40.0	--	--	95.0	95.0	--
Total Federal annual charges	855.0	781.4	676.8	1,458.2	1,020.3	286.7	1,307.0	835.7	723.6	676.8	1,400.4	916.6
4. NON-FEDERAL ANNUAL CHARGES												
a. Interest on non-Federal investment	382.9	362.0	--	362.0	378.1	--	378.1	238.1	316.1	--	316.1	425.5
b. Amortization of non-Federal investment	59.1	55.2	--	55.0	59.9	--	59.9	47.4	45.0	--	45.0	63.9
c. Maintenance and operation	50.0	49.0	--	49.0	50.0	--	50.0	50.0	50.0	--	50.0	123.0
Total non-Federal annual charges	492.0	466.2	--	466.2	488.0	--	488.0	425.5	411.1	--	411.0	612.4
5. TOTAL ESTIMATED ANNUAL CHARGES	1,347.0	1,247.6	676.8	1,924.4	1,508.3	286.7	1,795.0	1,261.2	1,134.7	676.8	1,811.5	1,529.0
BENEFITS AND BENEFIT TO COST RATIO												
1. TOTAL ESTIMATED ANNUAL BENEFITS	2,211.0			2,234.9			2,250.3	2,197.0			2,220.0	2,237.6
2. BENEFIT TO COST RATIO	1.6			1.2			1.3	1.7			1.2	1.5

(1) Reservoirs at Mud Hill and Lake Abilene sites
(2) Reservoir at Upper Lytle Creek site
(3) Exclusive of preauthorization cost

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TABLE 3

INVESTIGATED RESERVOIRS
(October 1961 price level)
(in 1000 dollars)

Item	Lake Abilene (plan A or C)	Mud Hill (plans A or C)	Upper Lytle Creek (plan B)
PERTINENT DATA			
Stream mile	53.8	40.6	6.6
Drainage area, square miles, total	101	137	49
Intercepted by Lake Abilene	--	101	--
Purpose (use)	Flood control	Flood control	Flood control
Type of dam	Earth fill	Earth fill	Earth fill
Length of dam, feet	8,400	15,000	16,000
Spillway:			
Type	Uncontrolled ogee	Uncontrolled ogee	Uncontrolled ogee
Location	In channel	On left bank	In channel
Net length, feet	400	400	285
Outlet works:			
Type	1-36" conduit	1-36" conduit	1-36" conduit
Control	1-36" sluice gate	1-36" sluice gate	1-36" sluice gate
Reservoir data:			
Sediment storage (acre-feet)	4,300	1,700	2,300
Spillway crest & top flood control pool (elevation)	2,044.0	1,870.0	1,789.0
Area (acres)	1,790	1,130	1,650
Capacity (acre-feet)	41,300	15,600	20,400
Maximum design water surface (elevation)	2,065.0	1,889.8	1,805.5
Area (acres)	2,710	2,170	3,380
Capacity (acre-feet)	88,500	48,000	61,600
Top of dam (elevation)	2,070.0	1,895.0	1,810.0
FIRST COSTS			
FEDERAL FIRST COST			
01.0 Lands and Damages	457.0	580.0	720.0
02.0 Relocations	75.0	250.0	130.0
04.0 Dam	6,400.0	5,800.0	4,880.0
a. Embankment	(2,224.0)	(2,175.0)	(2,310.0)
b. Slope protection	(16.0)	(18.0)	(20.0)
c. Spillway	(4,160.0)	(3,500.0)	(2,550.0)
d. Outlet works	--	(107.0)	--
08.0 Access Road	20.0	20.0	20.0
19.0 Building and Grounds	120.0	120.0	120.0
20.0 Operating Equipment	25.0	25.0	25.0
30.0 Engineering and Design	238.0	236.0	205.0
31.0 Supervision and Administration	365.0	369.0	300.0
TOTAL ESTIMATED PROJECT FIRST COST (1)	7,700.0	7,400.0	6,400.0
ANNUAL CHARGES			
(Construction period - 60 months) (Amortization period - 50 years) (Interest rate - 2-5/8%)			
FEDERAL INVESTMENT			
First cost	7,700.0	7,400.0	6,400.0
Preauthorization	5.0	5.0	5.0
Interest during construction	506.0	486.0	420.0
Total investment	8,211.0	7,891.0	6,825.0
ANNUAL CHARGES			
Interest on investment	215.5	207.1	179.2
Amortization	81.2	78.0	67.5
Maintenance and operation	50.0	45.0	40.0
TOTAL ANNUAL CHARGES	346.7	330.1	286.7

(1) Exclusive of preauthorization costs

TABLE 4

ANALYSES OF INVESTIGATED PLAN C
(in 1000 dollars)
(October 1961 price level)

Item	Flood frequency protection: 50-year	75-year	100-year
FIRST COSTS			
1. FEDERAL FIRST COST			
Railroad alterations	200.0	236.0	316.0
Channel	19,400.0	23,800.0	28,000.0
Levee and levee sluices	84.0	84.0	84.0
Engineering and design	716.0	900.0	1,100.0
Supervision and administration	1,200.0	1,480.0	1,700.0
Total Federal first cost	21,600.0	26,500.0	31,200.0
2. NON-FEDERAL FIRST COST			
Lands and damages	4,400.0	4,450.0	4,500.0
Alterations to highways and utilities	2,500.0	2,650.0	2,900.0
Total non-Federal first cost	6,900.0	7,100.0	7,400.0
3. TOTAL ESTIMATED FIRST COST OF PROJECT (1)	28,500.0	33,600.0	38,600.0
ANNUAL CHARGES			
(Construction period - 60 months)(Amortization period - 50 years)			
(Interest rates - Federal, 2.625%; non-Federal, 5% lands, 3% other costs)			
1. FEDERAL INVESTMENT			
a. Federal first cost	21,600.0	26,500.0	31,200.0
b. Preauthorization costs	100.0	100.0	100.0
c. Interest during construction on items a & b	1,424.1	1,745.6	2,054.1
Total Federal investment	23,124.0	28,346.0	33,354.0
2. NON-FEDERAL INVESTMENT			
a. Non-Federal first cost	6,900.0	7,100.0	7,400.0
b. Interest during construction	737.5	755.0	780.0
Total non-Federal investment	7,637.5	7,855.0	8,180.0
3. FEDERAL ANNUAL CHARGES			
a. Interest on Federal investment	607.0	744.1	875.5
b. Amortization of Federal investment	228.7	280.3	329.9
c. Maintenance and operation	--	--	--
Total Federal annual charges	835.7	1,024.4	1,205.4
4. NON-FEDERAL ANNUAL CHARGES			
a. Interest on non-Federal investment	328.1	335.8	346.7
b. Amortization of non-Federal investment	47.4	49.1	51.8
c. Maintenance and operation	50.0	51.0	52.0
Total non-Federal annual charges	425.5	435.9	450.5
5. TOTAL ESTIMATED ANNUAL CHARGES	1,261.2	1,460.3	1,655.9
BENEFITS AND BENEFIT-COST RATIO			
1. TOTAL ESTIMATED ANNUAL BENEFITS	2,197.0	2,210.7	2,218.0
2. BENEFIT TO COST RATIO	1.7	1.5	1.3

(1) Exclusive of preauthorization cost

TABLE 5

INVESTIGATED CHANNEL IMPROVEMENT
DYESS AIR FORCE BASE AREA
(October 1961 price level)

Item	Unit quantity	Unit cost	Quantity	Cost
FEDERAL FIRST COST				
(01.0) Lands and damages				
a. Fee simple lands	Acre	--	48.2	$ 28,000
b. Acquisition expense	L.S.	--	--	2,000
Subtotal				30,000
Contingencies, 15%+				4,500
Total				34,500
(02.0) Relocations				
a. Housing area access road bridge	L.S.	--	1	8,750
b. Pipe line	L.S.	--	1	10,000
c. Pipe line	L.S.	--	1	10,000
d. F.M.Hwy. 707 bridge	L.S.	--	1	8,750
Subtotal				37,500
Contingencies, 20%+				7,500
Total				45,000
(09.0) Channel				
a. Care of water	L.S.	--	--	22,000
b. Clearing	Acre	$150.00	72	10,800
c. Common excavation	C.Y.	0.75	901,000	675,750
d. Slope protection	Acre	500.00	25	12,500
Subtotal				721,050
Contingencies, 20%+				143,950
Total				865,000
(30.0) Engineering and design	L.S.	--	--	36,000
(31.0) Supervision and administration	L.S.	--	--	55,500
TOTAL ESTIMATED FIRST COSTS				$1,036,000
FEDERAL ANNUAL CHARGES				
(Construction period - 60 months) (Amortization period - 50 years) (Interest rate - 2-5/8%)				
1. Investment				
a. First costs				$1,036,000
b. Interest during construction				68,000
Total				$1,104,000
2. Annual charges				
a. Interest on investment				$ 29,000
b. Amortization of investment				10,900
c. Maintenance and operation				3,100
Total annual charges				$ 43,000
BENEFITS AND BENEFIT-COST RATIO				
1. Total estimated annual benefits				$ 5,700
2. Benefit to cost ratio				0.13

APPENDIX IV SUPPLEMENTAL DATA

TABLE 1

DETAILED ESTIMATE OF FIRST COST
PROPOSED PLAN OF IMPROVEMENT
(October 1961 price level)

Item	Unit quantity	Unit cost	Quantity	Cost
1. Federal first cost				
(02.0) Railroad alterations				
a. Abilene & Northern bridge	L.S.	--	--	$ 35,500
b. T&P bridges (3 crossings)	L.S.	--	--	167,000
c. Abilene & Southern bridge	L.S.	--	--	60,500
Subtotal				263,000
Contingencies, 20%+				53,000
Total - Railroad alterations				316,000
(09.0) Channel				
a. Care of water	L.S.	--	--	460,000
b. Clearing	Acre	$150.00	1,106	165,900
c. Excavation, common	C.Y.	0.75	18,508,000	13,881,000
d. Excavation, shale	C.Y.	0.90	1,580,000	1,422,000
e. Structural backfill	C.Y.	1.00	250,700	250,700
f. Concrete (including cement)	C.Y.	25.00	103,000	2,575,000
g. Reinforcing steel	Lb.	0.13	15,452,000	2,008,800
h. Riprap	C.Y.	6.00	328,800	1,972,800
i. Bedding	C.Y.	4.00	131,500	526,000
j. Slope protection	Acre	500.00	156	78,000
Subtotal				23,340,200
Contingencies, 20%+				4,659,800
Total - Channel				28,000,000
(11.0) Diversion dike				
a. Care of water	L.S.	--	--	4,200
b. Clearing	Acre	250.00	2	500
c. Stripping	C.Y.	0.25	25,000	6,250
d. Compacted fill	C.Y.	0.32	158,000	50,560
e. Slope protection	Acre	500.00	16	8,000
Subtotal				69,510
Contingencies, 20%+				14,490
Total - Diversion dike				84,000
(30.0) Engineering and design				1,100,000
(31.0) Supervision and administration				1,700,000
TOTAL ESTIMATED FEDERAL FIRST COST				31,200,000
2. Non-Federal first cost				
a. Lands and damages				
(1) Fee simple, lands, improvements	Acre	--	1,430	3,852,400
(2) Administrative costs	L.S.	--	--	40,000
Subtotal				3,892,400
Contingencies, 20%+				607,600
Total - Lands and damages				4,500,000
b. Relocations and alterations				
(1) Bridges and roads	L.S.	--	--	2,657,100
(2) Utilities	L.S.	--	--	242,900
Total - Relocations and alterations				2,900,000
TOTAL NON-FEDERAL FIRST COST				7,400,000
3. Total estimated first cost of project				$38,600,000

TABLE 2

NON-FEDERAL RELOCATIONS ESTIMATE OF FIRST COST
PROPOSED PLAN OF IMPROVEMENT
(October 1961 price level)

Item	Location	Cost
1. ROADS AND BRIDGES		
a. Elm & Little Elm Creeks Improved Channel		
(1) F-M Road 1193.	98+50	$ 38,000
(2) U.S. Hwy 83 &.277	191+70	9,000
(3) Old Anson Road	239+00	42,900
(4) U.S. Hwy. 83 & 277 alternate	292+00	34,000
(5) Interstate Hwy. 20	368+00	258,000
(6) County road	432+50	31,400
(7) U.S. Hwy. 80	484+50	85,000
(8) Parking area access road	486+00	7,800
(9) County road	561+30	33,600
(10) County road	612+63	32,800
b. Cat Claw Creek Improved Channel		
(1) Interstate Hwy. 20	39+00	38,100
(2) Vogel Ave.	78+40	9,100
(3) Ambler Ave.	95+57	7,000
(4) North 20th St.	105+60	8,100
(5) North 19th St.	111+00	8,000
(6) North 18th St.	113+00	6,000
(7) North 15th St.	124+00	5,400
(8) North 12th St.	140+00	7,000
(9) North 11th St.	146+00	12,100
(10) State St.	156+00	6,000
(11) North 3rd St.	179+00	6,000
(12) North 1st St.	190+00	6,000
(13) U.S. Hwy. 80	192+00	16,000
(14) Russell St.	200+00	16,600
(15) South 3rd St.	204+50	10,100
(16) South 5th St.	211+00	11,900
(17) South 7th St.	219+40	8,100
(18) Mockingbird Lane	226+00	13,800
(19) Sammons Drive	236+30	12,500
(20) South 9th St.	242+50	5,000
(21) South 11th St.	251+50	9,200
(22) South Willis St.	264+30	5,000
(23) South 14th St.	276+00	8,100
(24) Shopping center drive	280+00	5,000
(25) South 20th St.	306+00	6,000
(26) South 27th St.	336+50	3,000
(27) U.S. Hwy. 83 & 84 By-pass	360+49	38,000
(28) U.S. Hwy. 83 & 84 By-pass*	61+11	12,000
c. Cedar Creek Improved Channel and Diversion Channel		
(1) County road	120+00	59,000
(2) Interstate Hwy. 20	218+50	91,000
(3) Ambler Ave. (St. Hwy. 351)	270+00	87,000
(4) College Drive	307+80	87,300
(5) E. North 10th St.	329+00	75,500
(6) E. North 7th St.	348+00	60,500
(7) U.S. Hwy.80 N. access road	368+00	68,000
(8) U.S. Hwy. 80	368+70	90,000
(9) E. South 7th st.	402+00	58,000
(10) South 11th St. (State Hwy. 36)	419+50	65,000
(11) South 15th St.	439+50	64,000
(12) South 25th St.	487+00	6,500
(13) Access road	535+00	57,000
(14) U.S. Hwy.83 & 84	605+80	75,000
(15) U.S. Hwy 83 & 84 By-pass	627+80	290,000
(16) F-M Road 613 (Buffalo Gap)	677+20	80,000
(17) County road**	35+30	3,700
d. Lytle Creek Improved Channel		
(1) E. South 5th St.	20+00	5,200
(2) E. South 11th St.	51+20	37,000
Subtotal		2,230,900
Contingencies, 20%+		426,200
Total		2,657,100
2. UTILITIES		
a. Water		96,200
b. Gas		24,300
c. Sewer		81,900
Subtotal		202,400
Contingencies, 20%+		40,500
Total		242,900
3. TOTAL ESTIMATE OF FIRST COST - NON-FEDERAL RELOCATIONS		$2,900,000

*Cat Claw Creek tributary channel
**Kirby Lake tributary channel

TABLE 3

BRIDGE ALTERATIONS OR MODIFICATIONS
PROPOSED PLAN OF IMPROVEMENT

Location	Channel Station	Design W.S. Elevation (ft.M.S.L.)	Low Steel Elevation Existing (ft.M.S.L.)	Low Steel Elevation Required (ft.M.S.L.)	Proposed Alteration or Modification
ELM AND LITTLE ELM CREEKS IMPROVED CHANNEL					
F-M Road 1193	98+50	1650.0	--	1653.0	Construct 300' concrete slab & girder span bridge
Abilene & Northern Ry.	167+50	1655.8	1664.4	1658.8	Redrive piling in existing bridge
U.S. Hwy. 83 & 277	191+70	1659.5	1665.4	1662.5	Lengthen existing bridge - 60' concrete slab & girder span
Old Anson Road	239+00	1667.5	1670.5	1670.5	Replace existing bridge with 330' concerte slab & girder span bridge
U.S. Hwy. 83 & 277 (alt.)	292+00	1676.3	1689.4	1679.3	Lengthen existing bridge - 120' concrete slab & girder span
Interstate Hwy. 20	368+00	1690.1	--	1693.1	Construct 2 - 400' & 2 - 320' concrete slab & girder span bridges
County road	432+50	1700.7	--	1703.7	Construct 240' concrete slab & girder span bridge
Texas & Pacific Ry.	483+00	1709.0	1710.5	1712.0	Raise existing bridge
U.S. Hwy. 80	484+50	1709.2	1711.5	1712.4	Replace 2 existing bridges with 2 - 240' concrete slab & girder bridges
	485+50	1709.4	1711.2		
Parking area access road	486+00	1709.5	--	--	Replace existing low water crossing
County road	561+30	1723.8	--	1726.8	Construct 240' concrete slab & girder span bridge
County road	612+63	1737.2	1736.1	1740.2	Replace existing bridge with 242' concrete slab & girder span bridge
CAT CLAW CREEK IMPROVED CHANNEL					
Interstate Hwy. 20	39+00	1675.9	--	1678.9	Construct 60' concrete slab & girder span bridge
Vogel Ave.	78+40	1687.2	1688.0	1690.2	Replace existing bridge with 60' concrete slab & girder span bridge
Ambler Ave.	95+57	1691.7	1692.6	1694.7	Replace existing M.B.C.
North 20th St.	105+60	1694.3	--	1697.3	Replace low water crossing with 60' concrete slab & girder span bridge
North 19th St.	111+00	1695.7	--	1698.7	Replace low water crossing with M.B.C.
North 18th St.	113+00	1696.2	1697.3	1699.2	Replace existing M.B.C.
North 15th St.	124+00	1699.1	1697.2	1702.1	Replace existing pedestrian bridge
North 12th St.	140+00	1703.2	1703.3	1706.2	Raise existing M.B.C.
North 11th St.	146+00	1704.8	--	1707.8	Construct 70' concrete slab & girder span bridge
State St.	156+00	1707.4	1708.1	1710.4	Raise and lengthen existing M.B.C.
North 3rd St.	179+00	1713.4	1714.1	1716.4	Raise existing M.B.C.
North 1st St.	190+00	1716.2	1718.7	1719.2	Lower F.L. of existing M.B.C.
Texas & Pacific Ry.	190+80	1716.4	1720.1	1719.4	Replace 6 panels of existing bridge with concrete girder span
U.S. Hwy. 80	192+00	1716.7	1718.3	1719.7	Replace existing M.B.C. with 60' concrete slab & girder span bridge
Russell St.	200+00	1718.6	--	1721.6	Construct 90' concrete slab & girder span bridge
South 3rd St.	204+50	1719.6	1720.7	1722.6	Replace existing M.B.C. with 60' concrete slab & girder span bridge
South 5th St.	211+00	1720.9	1724.2	1723.9	Replace existing M.B.C. with 60' concrete slab & girder span bridge
South 7th St.	219+40	1722.7	1724.9	1725.7	Replace existing bridge with 60' concrete slab & girder span bridge
Mockingbird Lane	226+00	1724.0	1726.1	1727.0	Replace existing M.B.C. with 60' concrete slab & girder span bridge
Sammons Drive	236+30	1726.1	--	1729.1	Replace existing low water crossing with 60' concrete slab & girder span bridge
South 9th St.	242+50	1727.3	1729.3	1730.3	Replace existing M.B.C.
South 11th St.	251+50	1729.2	1730.7	1732.2	Replace existing bridge with 60' concrete slab & girder span bridge
South Willis St.	264+30	1731.7	1733.5	1734.7	Raise existing M.B.C.
South 14th St.	276+00	1734.0	1734.6	1737.0	Replace existing bridge with 60' concrete slab & girder span bridge
Shopping center drive	280+00	1734.9	1733.7	1737.9	Raise existing M.B.C.
South 20th St.	306+00	1740.1	1743.1	1743.1	Lower F.L. of existing M.B.C.
South 27th St.	336+50	1748.3	1749.5	1751.3	Raise & lengthen existing M.B.C.
U.S. Hwy. 83 & 84 By-pass	360+49	1755.0	1759.1	1758.0	Lengthen existing M.B.C.
U.S. Hwy. 83 & 84 By-pass*	61+11	1752.5	1753.0	1755.0	Raise & lengthen existing M.B.C.
CEDAR CREEK IMPROVED CHANNEL AND DIVERSION CHANNEL					
County road	120+00	1652.2	--	1655.2	Construct 440' concrete slab & girder span bridge
Interstate Hwy. 20	218+50	1659.4	1665.4	1662.4	Lengthen existing bridge - 260' concrete slab & girder span bridge
Ambler Ave. (St. Hwy. 351)	270+00	1667.6	1672.8	1670.6	Replace existing bridge with 420' concrete slab & girder span bridge
College Drive	307+80	1673.9	1677.6	1676.9	Replace existing bridge with 420' concrete slab & girder span bridge
East North 10th St.	329+00	1678.2	1680.2	1681.2	Raise and lengthen existing bridge - 230' concrete slab & girder span bridge
East North 7th St.	348+00	1682.7	1681.6	1685.7	Raise and lengthen existing bridge - 180' concrete slab & girder span bridge
U.S. Hwy. 80 North Access Rd.	368+00	1687.7	1688.9	1690.7	Replace existing bridge with 390' concrete slab & girder span bridge
U.S. Hwy. 80	368+70	1687.9	1690.1	1690.9	Raise and lengthen existing bridge 250'
Texas & Pacific Ry.	374+80	1689.5	1699.1	1692.5	Lengthen existing bridge
East South 7th St.	402+00	1695.8	1694.3	1698.8	Replace existing bridge with 360' concrete slab & girder span bridge
South 11th St. (St. Hwy. 36)	419+50	1700.0	1700.0	1703.0	Replace existing bridge with 360' concrete slab & girder span bridge
South 15th St.	439+50	1705.1	1702.3	1708.1	Replace existing bridge with 400' concrete slab & girder span bridge
South 25th St.	487+00	1717.4	--	--	Replace existing low water crossing
Access road	535+00	1732.0	--	1735.0	Construct 280' concrete slab & girder span bridge
U.S. Hwy. 83 & 84	605+80	1753.3	1753.8	1756.3	Replace existing M.B.C. with 4 - 330' concrete slab & girder span bridges
Abilene & Southern Ry.	623+50	1759.0	1763.4	1762.0	Redrive piling & lengthen existing bridge
U.S. Hwy. 83 & 84 By-pass	627+80	1760.2	1761.9	1763.2	Replace existing M.B.C. with 400' concrete slab & girder span bridge
F-M Road 613 (Buffalo Gap Rd.)	677+20	1770.5	--	1773.5	Construct 240' concrete slab & girder span bridge
County Road**	35+30	1746.4	--	--	Construct low water crossing
LYTLE CREEK IMPROVED CHANNEL					
East South 5th St.	20+00	1692.5	--	--	Replace existing low water crossing
East South 11th St. (St. Hwy. 36)	51+20	1697.5	1703.4	1700.5	Lengthen existing bridge - 210' concrete slab & girder span bridge

* Cat Claw Creek improved tributary channel
** Kirby Lake improved tributary channel
M.B.C. - multiple box culvert

TABLE 4

PERTINENT DATA
PROPOSED PLAN OF IMPROVEMENT

LOCATION	Abilene Area, Texas
STREAMS	RIVER MILE LIMITS
Elm Creek	11.3 to 30.2
Little Elm Creek	0.0 to 6.7
Cat Claw Creek	0.0 to 7.8
Cedar Creek	0.0 to 16.0
Lytle Creek	0.0 to 1.2
Buttonwillow Creek	0.0 to 4.0
STANDARD PROJECT DATA	
Storm rainfall, inches	15.50
Storm duration, hours	96
Flood volume, inches	10.60
DESIGN DATA (CHANNELS)	
Storm rainfall, inches	7.31
Storm duration, hours	24
Flood volume, inches	5.22

PEAK DISCHARGE DATA AT SELECTED LOCATIONS

Location	Drainage Area (sq.mi.)	Standard Project Flood Discharges (cfs)	Design Flood Discharge (cfs)
IMPROVED CHANNELS - CEDAR, LYTLE, BUTTONWILLOW, AND DIVERSION CHANNEL			
Elm Creek above diversion channel	148	74,900	37,800
Improved Cedar Creek at U.S.Hwy. 80-84	273	125,800	60,000
Improved Cedar Creek above Rainy Creek	280	126,100	60,200
Improved Cedar Creek above Elm Creek	342	151,100	78,800
IMPROVED CHANNELS - ELM, LITTLE ELM, AND CAT CLAW CREEKS			
Little Elm Creek above head of improvement	58	45,900	25,600
Little Elm Creek at U.S.Hwy. 80-84	62	46,400	26,800
Elm Creek at U.S.Hwy.80-84	8.2	7,900	4,700
Elm Creek below Little Elm Creek	77	53,500	29,300
Cat Claw Creek at U.S.Hwy. 80-84	6.5	8,900	6,300
Elm Creek below Cat Claw Creek	107	68,700	36,300
Elm Creek below Cedar Creek	456	220,800	114,800

CHANNEL IMPROVEMENT (Enlargement, realignment, and diversion)	
Length of existing channel below improvement, miles	55.8
Length of improved channel and diversion, miles	40.1
Length of improved channel and diversion, feet	211,900
Channel excavation, cubic yards	20,088,000

PROPOSED IMPROVED CHANNEL RIGHTS-OF-WAY

Item	Stations From	Stations To	Right-of-way (feet)
Elm and Little Elm Creeks improved channel	40+00	64+00	500
	64+00	70+00	Transition
	70+00	340+00	350
	340+00	343+00	350
	343+00	612+63	350
Cat Claw Creek improved channel	0+00	360+50	90
	0+00 (1)	28+50	90
	28+50	30+00	Transition
	30+00	61+11	70
Cedar Creek improved channel and diversion channel	64+00	374+80	500
	374+80	377+00	Transition
	377+00	660+00	450
	660+00	670+00	450
	670+00	762+00	450
	0+00 (2)	49+21	250
	0+00 (3)	62+00	350
Diversion dike	0+00	122+00	200

(1) Cat Claw Creek tributary channel
(2) Improved channel to Kirby Lake
(3) Improved channel to Lytle Lake

DIVERSION DIKE	
Freeboard, minimum above design water surface, feet	4
Length, feet	12,200
Crown width, feet	10
Minimum berm width, feet	100
Side slopes	1 on 2.5
Average height, feet	10
Compacted fill, cubic yards	158,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
P. O. BOX 1306

District Engineer
Corps of Engineers, U. S. Army
P. O. Box 1600
Fort Worth 4, Texas

August 1, 1961

Dear Sir:

This letter constitutes our report on the Brazos River and Tributaries, Clear Fork of the Brazos River, Flood Protection - Abilene Area, Taylor and Jones Counties, Texas. This report is intended to accompany your Interim Report and has been prepared under the authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). The Texas Game and Fish Commission cooperated in the preparation of this report and has concurred in its contents by letter of July 19, 1961, signed by Executive Secretary Howard D. Dodgen.

We understand that three plans, referred to as A, B, and C, are being investigated for flood protection of the city of Abilene. In all plans, consideration is being given to a western diversion channel and an eastern diversion channel which would skirt around the city of Abilene to confluence at Cedar Creek northeast of the city. Drainage from these diversions would be made into the existing Lake Fort Phantom Hill. Feasibility of leveeing the diversion channels will also be studied. Plan B would also include a diversion dam on Lytle Creek which would divert water into existing Lytle Lake.

In Plan A, the western diversion channel would originate at Cat Claw Creek, south of Abilene, and proceed generally in a northerly direction, intercepting Elm Creek and Little Elm Creek. It would join Cedar Creek northeast of Abilene. The eastern diversion channel would begin at Buttonwillow Creek, slightly northwest of Kirby Lake, and generally follow the course of that creek and Cedar Creek northward, passing on the eastern edge of Abilene to confluence with the western diversion channel northeast of Abilene.

In Plan B, the western diversion channel would begin at the northwest corner of Kirby Lake and proceed generally in a northerly direction and follow about the same course as given in Plan A. The eastern diversion channel would begin at Cedar Creek, north of Kirby Lake,

and follow the course of that creek to join the western diversion channel in the same vicinity as in Plan A. A diversion dam would also be constructed on Lytle Creek east of Kirby Lake and divert floodwaters into that lake.

In Plan C, the western diversion channel would begin at Little Elm Creek, southeast of Abilene, and follow the course of that stream and the lower portion of Elm Creek. It would be confluent with Cedar Creek in the same vicinity as in Plan A. The eastern diversion channel would begin at Elm Creek, southwest of Abilene, and proceed easterly to intercept Buttonwillow Creek. It would then follow the course of that stream and Cedar Creek to join the western diversion channel as in Plan A.

Most of the project area is urban and has no fishery habitat and only insignificant wildlife habitat. The construction of the project may temporarily result in increased turbidity in Lake Fort Phantom Hill. This effect, however, will be alleviated when bank stabilization is achieved in the new channels. The project will have no effects upon wildlife resources.

This report is based upon engineering information received from your staff as of March 9, 1961, and any modifications should be brought to the attention of the Bureau of Sport Fisheries and Wildlife and the Texas Game and Fish Commission. The cooperation of the Fort Worth District Corps of Engineers in furnishing engineering data and planning information is appreciated.

Sincerely yours,

/s/ John C. Gatlin

John C. Gatlin

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
Ninth Floor - 1114 Commerce Street
Dallas 2, Texas

PUBLIC HEALTH SERVICE

October 31, 1961

Lt. Col. Leslie E. Pierson
Acting District Engineer
Corps of Engineers
U. S. Army Engineer District
100 West Vickery Boulevard
Fort Worth 4, Texas

Dear Colonel Pierson:

A review has been made of the report "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River Flood Protection - Abilene Area", dated October 1961.

Plan C of the report, which is considered the most desirable, provides for diversion of flows down an improved Cedar Creek channel, as well as improved channels along Elm, Little Elm, and Cat Claw Creeks. No reservoir construction is included.

The Plan of Improvement should have no adverse effects on existing impoundments. Reduction of flooding to residential and commercial developments should be helpful to general sanitation conditions.

Sincerely yours,

/s/ E. C. Warkentin

E. C. Warkentin
Associate Director for
Environmental Health Services

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
REGION IV

ROOM 206 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA

October 31, 1961

Lt. Col. Leslie E. Pierson
Acting District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas

File: SWFGP

Dear Colonel Pierson:

Thank you for sending the Bureau of Mines a draft copy of "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area" dated October 1961, for our review and comments.

The report indicates an immediate need for channel improvement and a diversion dike along Elm, Little Elm, Cat Claw, Cedar, Lytle, and Buttonwillow Creeks. All of these creeks run through the city of Abilene and join in Elm Creek and then into Lake Fort Phantom Hill Reservoir which empties into the Clear Fork of the Brazos River. The Elm Creek Watershed, including all of the above creeks, lies mainly in Taylor County but extends northward into Jones County, Texas. This watershed is 52 miles in length, has a maximum width of 23 miles and an area of 485 square miles.

It was noted that many plans of improvement were considered to alleviate serious flooding in the city of Abilene, Texas. The suggested plan is to build a diversion dike and two diversion channels. The diversion dike will divert flows from the upper parts of Elm and Cat Claw Creeks to a diversion channel; it also will divert all flows from Buttonwillow and Rainy Creeks into Cedar Creek along the eastern edge of the city of Abilene to Elm Creek. The plan also proposes to extend the existing diversion channel around Dyess Air Force Base on Little Elm Creek to handle Indian Creek, and the remainder of Cat Claw Creek and Elm Creek along the western edge of the city of Abilene via Elm Creek.

Total initial cost of this channel improvement project, estimated at $38,600,000, is composed of $7,400,000 nonfederal funds for land, damages, relocations and alteration, and $31,200,000 of Federal funds principally for channel and diversion dike costs.

There are numerous oil and gas fields located south, east, and west of the project area, but none in the project area. Two gas pipelines (6-inch and 8-inch diameter) of Lone Star Gas Co. cross the project area, essentially in a west to east direction. These two pipelines pass just north of Lake Kirby and will require protection where they cross the diversion channel and diversion dike just west of Lake Kirby. The petroleum refinery of Debco Corp. is situated along one diversion channel of the project on the east side of Abilene.

Clay deposits in the project area just north of the Abilene townsite are mined in open pits for manufacture of brick by Abilene Brick Co. The entire area contains numerous commercial deposits of sand and gravel. This material is produced by Atlas Sand and Gravel Co. and Caton Sand and Gravel Co. Just south of the project area, limestone exists near the surface and is quarried for concrete aggregate and roadstone. Adequate supplies of sand and gravel and limestone may be found in the area for the proposed construction.

An office study of Bureau of Mine's records indicates the proposed channel improvements will have no adverse effects on the mineral industries of the area; flood protection may be beneficial to these industries. The Regional Office of the Bureau of Mines has no objection to the proposed project. No current field examination was made of the project.

Sincerely yours,

/s/ R. S. Sanford

R. S. Sanford
Acting Regional Director
Region IV

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
P. O. BOX 1306
ALBUQUERQUE, NEW MEXICO

November 1, 1961

District Engineer
Corps of Engineers, U. S. Army
P. O. Box 1600
Fort Worth, Texas

Dear Sir:

Reference is made to your letter dated October 26, 1961, requesting comments on your proposed Interim Review of Report on Brazos River and Tributaries, Texas, covering Clear Fork of Brazos River, Flood Protection - Abilene Area. Your proposed report adequately presents the views of the Bureau of Sport Fisheries and Wildlife. Hence, we have no additional comment to offer.

Sincerely yours,

/s/ Carey H. Bennett

Carey H. Bennett, Chief
Division of Technical Services

cc: Field Supervisor, Branch of River Basin Studies, Bureau of Sport Fisheries and Wildlife, Fort Worth, Texas

FEDERAL POWER COMMISSION
REGIONAL OFFICE
100 North University Drive
Fort Worth 7, Texas

The District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas

Dear Sir:

We have received your memorandum of October 26, 1961, including a copy (serial No. 73) of your "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area," dated October 1961.

We have examined the report with particular attention to the recommended program's effects on hydroelectric power potentialities. We find that the nature of the recommended works (channel rectification in conjunction with a dike) do not lend themselves to adaptation for purposes of hydroelectric power development and will not affect any existing or potential hydroelectric resources.

It is to be noted that these comments are submitted at field level and are not to be construed as opinions of the Federal Power Commission. We appreciate the opportunity to review the report which is returned herewith in accordance with your request.

Sincerely yours,

Edgar S. Coffman
Regional Engineer

By /s/ Lenard B. Young
Acting

Enclosure No. 103415:
As stated above

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGIONAL OFFICE, REGION 5
P. O. BOX 1609
AMARILLO, TEXAS

November 9, 1961

Lt. Col. Leslie E. Pierson, Acting District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
100 W. Vickery Boulevard
Fort Worth 4, Texas

Dear Colonel Pierson:

We appreciate your October 26, 1961, letter transmitting to this office and our Austin Development Office your "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area," dated October 1961.

The proposed project, which would provide desirable local protection improvements, would not adversely affect any existing or potential Bureau of Reclamation projects.

Your courtesy in providing our offices an opportunity to review and comment on your report is appreciated.

Sincerely yours,

/s/ John Thompson

Acting Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

Region Three
Santa Fe, New Mexico

November 14, 1961

District Engineer
U. S. Army Engineer Dist, Fort Worth
P. O. Box 1600
Fort Worth, Texas

Dear Sir:

Thank you for the opportunity of reviewing the draft copy (serial number 60) in final form of your "Interim Review of Reports on Brazos River, covering Clear Fork, Flood Protection - Abilene Area". Our review discloses that we have no comments to make.

/s/ George W. Miller

George W. Miller
Assistant Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
SOUTHWESTERN POWER ADMINISTRATION
POST OFFICE DRAWER 1619
TULSA 1, OKLAHOMA

November 15, 1961

Your reference:
SWFGP

District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas

Dear Sir:

Thank you for your letter of October 26, 1961, enclosing a draft copy of the "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area."

The proposed channel improvements will not affect the interests of this Administration.

Sincerely yours,

/s/ Douglas G. Wright

Douglas G. Wright
Administrator

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SOUTHWEST FIELD COMMITTEE, REGION SIX
807 Brazos Street
Austin 14, Texas

November 17, 1961

District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas

Dear Sir:

I have reviewed the Corps of Engineers' report (Serial No. 71), "Interim Review of Reports of Brazos River and Tributaries, Texas Covering Clear Fork of Brazos River Flood Protection - Abilene Area", dated October 1961, that was transmitted to me with your letter of October 26, 1961 for review and comments.

The report points out, page 8, that "There are no stream-gaging stations in the Elm Creek watershed. Consequently, records indicating the extent and frequency of flooding are very meager, consisting primarily of references to periods of high water taken from the files of local newspapers."

Although this office has not had time to make detailed hydrologic studies of the area covered by this report, the design discharge criteria to contain the flows produced by rainfall having a recurrence interval of 100 years, as discussed on page 25 of the report, appears reasonable. The primary basis for this statement is as follows:

The Geological Survey has records of discharge on Deep Creek subwatershed No. 8 near Placid, Tex., (drainage area 4.32 square miles) for the period 1952 to 1961. A preliminary analyses of rainfall and runoff for that area have recorded flood flows resulting from various storms during that period, one of which was the result of a 7.8 inch rainfall in a 24-hour period, Oct. 4, 1953. The resulting runoff from this storm was 3.1 inches. This watershed is approximately 90 miles south by east from Abilene.

In view of the fact that there are no streamflow stations on small watersheds in the Abilene area and that the City of Abilene is expected to expand into what are now rural area, it is recommended that the report include recommendations for an appropriate network

of hydrologic stations (rainfall and streamflow) that would not only obtain hydrologic data that will be needed in planning new or rehabilitating existing flood control facilities, but also the data will be valuable in studying channel hydraulics and watershed hydrology for storms that may occur and which exceed the designed storm.

The report recommends that the operation and maintenance of the flood facilities be paid by local interests. It would seem appropriate, therefore, that the construction cost include the installation and operation and maintenance of appropriate hydrologic equipment.

The Geological Survey will be glad to give any assistance possible to this problem.

Very truly yours,

/s/ Trigg Twichell

Trigg Twichell
Geological Survey
Member, SWFC

cc: Douglas R. Woodward,
Staff Engr., Washington, D. C.

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

SWFGP

22 November 1961

Mr. Trigg Twichell, District Engineer
Geological Survey
U. S. Department of the Interior
Southwest Field Committee, Region Six
807 Brazos Street
Austin 14, Texas

Dear Mr. Twichell:

This is in reply to your letter of 17 November 1961, concerning your comments on our report, "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area."

Your concurrence in the reasonableness of the computed design flow is noted. Your recommendation that the report include recommendations for the establishment of an appropriate network of hydrologic stations (rainfall and streamflow) is noted. The matter will be given full consideration subsequent to authorization and during the preconstruction planning phase of the project.

Your comments and my reply are being reproduced and will be appended to the report for the information of higher authority.

Sincerely yours,

R. P. WEST
Colonel, CE
District Engineer

U. S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
P. O. BOX 12037
FORT WORTH 16, TEXAS

November 21, 1961

Lt. Colonel Leslie E. Pierson
Acting District Engineer
U. S. Army Corps of Engineers
100 West Vickery Boulevard
Fort Worth 4, Texas

Dear Colonel Pierson:

Reference is made to your letter 26 October 1961 addressed to Mr. L. S. Coy, Division Engineer, Austin, Texas, and to the draft copy in final form of your "Interim Review of Reports of Brazos River and Tributaries, Texas, covering Clear Fork of Brazos River Flood Protection - Abilene Area" dated October 1961. An informational copy of this letter together with draft copy Serial No. 72 was forwarded to this Regional office.

The draft copy of your Interim Review has been reviewed by our Austin Division office insofar as it relates to its effect on the Federal-aid highway system in Texas. The comments of our Division office are incorporated in Division Engineer Coy's letter dated November 20, 1961, the original copy of which is attached hereto. The regional office has no additional comments to those made by our Division Engineer.

We appreciate the opportunity you have afforded the Division and Regional offices to review and comment on your proposed draft copy.

Sincerely yours,

/s/ C. T. Nitteberg

C. T. Nitteberg
Regional Bridge Engineer

Attachment 1

cc:
L. S. Coy, Austin
S. E. Ridge, Washington, D. C.

U. S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
404 V.F.W. Building
Austin, Texas

November 20, 1961

Lt. Colonel Leslie E. Pierson
Acting District Engineer
U. S. Army Corps of Engineers
100 West Vickery Boulevard
Fort Worth 4, Texas

Dear Colonel Pierson:

The draft copy (serial number 74) of your "Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area," forwarded with your letter dated October 26, 1961, has been reviewed.

It is noted that the proposed project, plan C, requires the construction, replacement and modification of 33 highway bridges, 19 multiple-box culverts and 7 low water crossings. The report proposes that the cost, which is estimated to be $2,657,100, will be a local interest obligation. However, the cost of the railroad modification has been considered a Federal cost obligation.

Many of the highways affected by the proposed project are on the Federal-aid highway system. Interstate Highway 20 is on the Interstate and Defense Highway system. The Abilene segment of the route has been recently completed to full standards at a copy of over $10,000,000 in State and Federal funds. State Highways 351, 36, and U. S. Highways 80, 83 and 83 by-pass routes are on the primary system. Farm to Market Highways 2404 and 613 are on the secondary system. The basic regulations of the Bureau of Public Roads will not permit the use of Federal-aid highway funds to be used to relieve local interests of obligations they agree to assume as a condition of any approved project.

From our investigation during the construction of highways in the Abilene vicinity, we know that there is a real need for flood protection and channel improvement work. If such a plans as is now proposed had been in operation or approved before our recent highway construction in Abilene, it would have been possible to eliminate or materially reduce the cost of the highway bridge reconstruction costs now contemplated.

The recommendations of this office are as follows:

1. All work proposed on the highway system should be co-ordinated with the Texas Highway Department. We are particularly concerned about the work proposed on Interstate Highway 20. This is a limited access facility designed for 1975 traffic of 13,500 vehicles per day. The safe handling of traffic of this magnitude is a serious problem.

2. All existing structures should be utilized to the maximum possible extent.

We appreciate the opportunity to review the report and will co-operate with any proposed project to the fullest extent possible.

Sincerely yours,

/s/ L. S. Coy

L. S. Coy
Division Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

P. O. Box 417
Temple, Texas
November 22, 1961

Colonel R. Paul West
District Engineer
U. S. Corps of Engineers
100 West Vickery Blvd.
P. O. Box 1600
Fort Worth, Texas

Dear Colonel West:

Thank you for the opportunity to review the Interim Review of Reports on Brazos River and Tributaries, Texas, covering Clear Fork of Brazos River, Flood Protection - Abilene Area. The following comments are presented for your consideration:

Page 2, Paragraph 5 - The Upper Brazos River Basin was not one of the watersheds in which the Department of Agriculture was authorized by the Flood Control Act of 1944, to undertake a program of runoff and waterflow retardation and soil erosion prevention. All assistance by the Soil Conservation Service in planning and installation of upstream projects for watershed protection and flood prevention in the Brazos River Basin is furnished under provisions of Public Law 566, as amended. Consequently, it appears the first sentence of Paragraph 5 should be deleted or replaced with the following:

"The Soil Conservation Service, United States Department of Agriculture, is authorized by the Watershed Protection and Flood Prevention Act (Public Law 566) to provide assistance in planning and installation of works of improvement for flood prevention or the conservation, development, utilization and disposal of water in creek watersheds of the basin."

Page 27, Paragraph 57 - The growth factor based on expected developments for the City of Abilene as indicated by the base study was used in estimating project benefits. It is felt that the report would be strengthened if it could be shown that future development or growth in the flooded area would be equal, relatively speaking, to that indicated for Abilene.

Very truly yours,

/s/ N. P. Stephenson

for H. N. Smith
State Conservationist

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

SWFGP

28 November 1961

Mr. H. N. Smith, State Conservationist
Soil Conservation Service
U. S. Department of Agriculture
P. O. Box 417
Temple, Texas

Dear Mr. Smith:

This is in reply to your letter of 22 November 1961 which presented comments of the Soil Conservation Service on our draft copy of Interim Review of Reports on Brazos River and Tributaries, Texas, Covering Clear Fork of Brazos River, Flood Protection - Abilene Area.

The first sentence of paragraph 5, page 2, of the report will be changed to conform to your suggested wording in order that the proper authority for studies by the Soil Conservation Service may be cited.

Your comments are being reproduced and will be appended to the report for the information of higher authority.

Your cooperation in reviewing and commenting on the Abilene report is appreciated.

Sincerely yours,

R. P. WEST
Colonel, CE
District Engineer

87780 O-62—7

CITY OF ABILENE

P. O. BOX 60

November 30, 1961

Colonel R. Paul West, District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas

Dear Colonel West:

Reference is made to our visit to your office on 8 November 1961, at which time we discussed the development of your plan for flood control for Abilene. You also explained to us the requirements for local co-operation for projects of this type.

It is our understanding that local interests, in this case the City of Abilene, would generally participate in the proposed plan as follows:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction, maintenance, and operation of the project.

b. Provide without cost to the United States all relocations of buildings and utilities, highway bridges, sewers, etc.

c. Provide assurances that encroachment on improved channels will not be permitted.

d. Provide without cost to the United States designated fill areas for the disposal of excess materials from the channel excavation work. These areas must be within reasonable haul distance of the project (approximately 5 miles).

e. Agree to publicize the residual flood plain information to the community and area concerned and to provide zoning and other regulatory agencies and public information media with this information for their guidance and appropriate action.

f. Hold and save the United States free from damages due to the construction of the project

g. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

You can be assured the citizens of Abilene are most cognizant of the seriousness of our potential flood damage. As a result of the discussion on the proposed plan of improvement, it is felt that the plan as briefly presented in a summary fashion should provide the required flood protection for the City of Abilene. It is further believed that the voters of Abilene would be receptive to endorsing a reasonable plan for flood protection.

Sincerely yours,

/s/ C. R. Kinard

C. R. Kinard
Mayor

FLOOD PROTECTION - ABILENE AREA
ELM CREEK, INCLUDING CAT CLAW CREEK
CLEAR FORK OF BRAZOS RIVER, TEXAS

INFORMATION CALLED FOR BY
SENATE RESOLUTION 148, 85TH CONGRESS
ADOPTED 28 JANUARY 1958

1. Authority.- The following information is furnished in response to Senate Resolution 148, 85th Congress, Second Session, adopted 28 January 1958.

2. Flood problem.- The principal flood problem on Elm Creek and its tributaries exists above Fort Phantom Hill Reservoir in the vicinity of Abilene, particularly in the following flood plain areas:

a. Elm Creek from mile 15.3 to 31.8

b. Little Elm Creek from mile 0.0 to 6.7 and within Dyess Air Force Base area

c. Cat Claw Creek from mile 0.0 to its intersection with the southern loop of U.S. Highway 83, mile 7.7

d. Cedar Creek from mile 0.0 to 15.8

e. Lytle Creek from mile 0.0 to 1.2

f. Buttonwillow Creek from mile 0.0 to 3.1

3. The developments in these areas are located principally within the corporation limits of Abilene and are as follows:

a. Elm Creek contains seven major highway crossings, one major railroad crossing, four county or street crossings, and numerous utility crossings.

b. Little Elm Creek contains one major highway crossing, one major railroad crossing, three county or street crossings, and several utility crossings.

c. Cat Claw Creek contains three major highway crossings, one major railroad crossing, twenty-four county or street crossings, and numerous utility crossings.

d. Cedar, Lytle, and Buttonwillow Creeks contain seven major highway crossings, two major railroad crossings, ten county or city street crossings, and numerous utility crossings.

4. Residential property contributes the greatest single item to the total flood damage with the heaviest concentration of dwelling

units in the western section, primarily along Cat Claw and Elm Creeks. Several shopping centers have been developed along the major highways and center of the western section, particularly along Highway 80. Most of the schools and churches have also been constructed in this section. The utility companies have most of their plants on the east side along Cedar Creek. There are several cemeteries in the west flood plain north of Highway 80. A municipal golf course, a country club, and various parks occupy part of the southern section of the flood plain.

5. Recommended plan of improvement.- The recommended plan of improvement, described as plan C in the basic report, provides for channel improvements with a diversion dike and consists of the following features:

a. The construction of about 11.6 miles of channel improvement along the general alignment of Elm and Little Elm Creeks, beginning at the southern edge of Lake Fort Phantom Hill and ending at the Dyess Air Force Base east property line on Little Elm Creek.

b. The construction of about 7.9 miles of improved channel along Cat Claw Creek (including 1.12 miles of tributary channel) from station 244+35 on the improved channel of item a to the U.S. Highway 83 and 84 By-pass on the south.

c. The construction of about 14.4 miles of improved channel along the general alignment of Cedar and Buttonwillow Creeks, beginning at the southern edge of Lake Fort Phantom Hill and extending around the southern city limits to intercept Cat Claw and Elm Creeks.

d. The construction of about 1.2 miles of improved channel along Lytle Creek from station 374+80 on the improved channel of item c to Lytle Lake Dam.

e. The construction of about 0.9 mile of improved channel along Cedar Creek from station 544+40 on the improved channel of item c to about 2,000 feet north of Kirby Lake Dam.

f. Minor cleaning and snagging of 5.4 miles of the existing Elm Creek channel between station 388+00 on the improved channel of item a to the upstream crossing of the U.S. Highway 83 and 84 By-pass on the south.

6. Local interests would be required to comply with all the requirements as generally set forth for local protection type projects. The requirements are: (1) provide without cost to the United States all land, easements, and rights-of-way necessary for the construction, maintenance, and operation of the project, (2) provide without cost to the United States designated fill areas for the disposal of excess materials from the channel excavation, (3) make any alterations and relocations to existing improvements required for the construction of the project, (4) hold and save the United States free from damages

due to the construction of the project, (5) agree to publicize the residual flood plain information in the community and area concerned and to provide zoning and other regulatory agencies and public information media with the information, and (6) maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.

7. Project cost and economic analysis.- The total first cost of the project, exclusive of preauthorization costs ($100,000), is estimated as $38,600,000 on the basis of October 1961 price levels, of which $31,200,000 is the Federal construction cost and $7,400,000 is the non-Federal cost for lands and alterations to channel dams, bridges, and utilities. The estimated annual charges shown in the basic report are $1,369,600, of which $1,317,600 is for interest and amortization computed on the basis of 2.625 percent for Federal costs, 5.0 percent for lands, and 3.0 percent for other project costs, and $52,000 is for operation and maintenance by local interests. The amortization and interest were computed on a basis of 100-year life with a 5-year construction period.

8. Benefits and benefit-cost ratio.- The total average annual benefits credited to the project are estimated to be $2,218,000, all for the prevention of flood damages. The benefit-cost ratio on the basis of a 100-year economic life is 1.6 to 1 as shown in the basic report. Analysis on the basis of a 50-year economic life indicates an increase in annual costs to $1,655,900 and a decrease in the benefit cost ratio to 1.3 to 1.

9. Physical feasibility and provisions for future needs.- The proposed project (plan C) was found to be the most practical and most economically justified of all plans investigated and will provide full protection for the flood produced by a 100-year storm. Additional studies indicated that the plan could be made more attractive by placing a diversion dike along the upper end of the improved channel which would divert the standard project flood from the highly developed areas along Elm and Cat Claw Creeks.

10. Extent of interest in project.- Local interests, represented by the City of Abilene, have indicated general approval and support of the proposed project, and no objections are known to exist.

11. Alternative projects.- Consideration was given to possible alternative projects in studies for the basic report. The following additional plans were investigated for the resolution of the flood problems on Elm Creek and tributaries in the vicinity of Abilene:

a. Plan A consists of a diversion channel beginning at Cat Claw Creek, crossing Elm Creek, and extending down Little Elm and Elm Creeks to the latter's confluence with Cedar Creek, thence to the headwaters of Lake Fort Phantom Hill. A companion channel begins at Buttonwillow Creek and extends down Cedar Creek to its confluence with

Elm Creek. This plan would cause the bulk of the flood flow to be carried on the west side of Abilene where the greatest growth is being experienced.

b. Plan B consists of a diversion channel beginning at Kirby Lake on Cedar Creek, crossing Buttonwillow, Cat Claw, and Elm Creeks, and extending down Little Elm and Elm Creeks as in plan A. The plan includes a detention dam on Lytle Creek (Lytle Creek Dam) and a small channel along Cedar Creek downstream from the municipal golf course. This plan would also cause the bulk of the flood flow to be carried on the west side of Abilene.

c. Plan D consists of a diversion channel beginning at Cat Claw Creek and proceeding as in plan A. Cedar Creek would be diverted into the Rainy Creek watershed on the east, and flowage easements would be obtained along Rainy Creek to the headwaters of Lake Fort Phantom Hill.

d. Plan A-1 is the same basic plan as plan A, with the addition of Lake Abilene and Mud Hill Reservoir.

e. Plan C-1 is the same basic plan as plan C, with the addition of Lake Abilene and Mud Hill Reservoir.

All plans would require improvement of Cat Claw and Elm Creek channels below the point of diversion, extending through the city.

12. The preliminary comparative studies provided for protection against a 50-year flood, and costs were amortized on the basis of a 50-year economic life. A summary of first costs, annual charges, annual benefits, and benefit-cost ratio is tabulated below for the alternative plans and for plan C which was expanded into the plan of improvement discussed above.

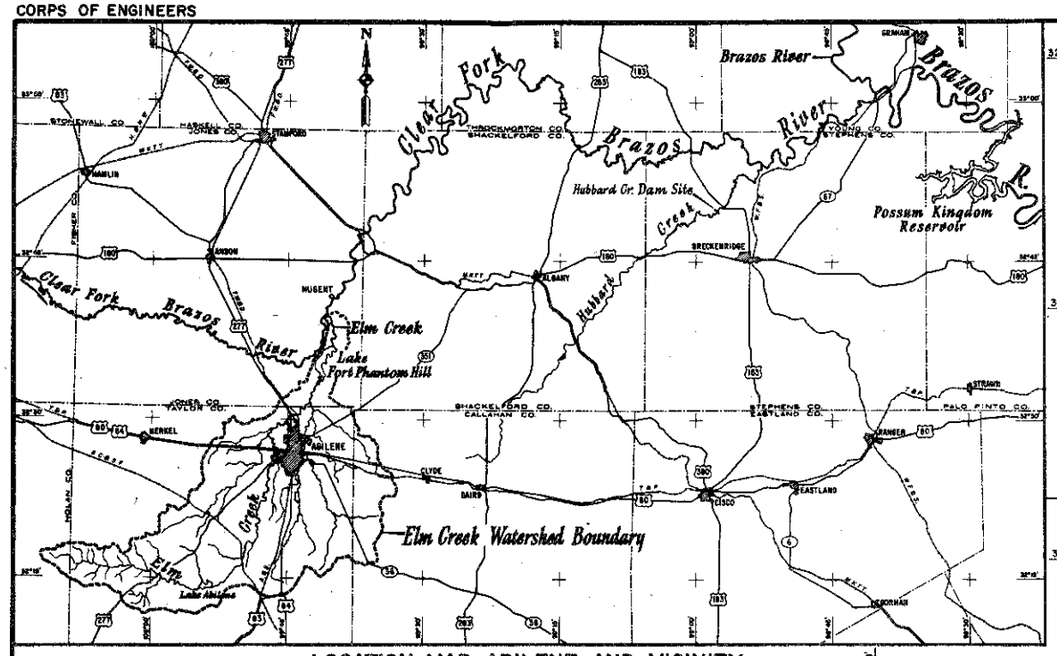
Plan	Construction Cost	Annual Charges	Annual Benefits	Benefit-Cost Ratio
A	$30,400,000	$1,347,000	$2,211,000	1.6 to 1
B	41,100,000	1,795,000	2,250,300	1.3 to 1
C	28,500,000	1,261,200	2,197,000	1.7 to 1
D	32,800,000	1,529,000	2,237,600	1.5 to 1
A-1	43,100,000	1,924,400	2,234,900	1.2 to 1
C-1	40,400,000	1,811,500	2,220,900	1.2 to 1

Analysis on the basis of economic life of 100 years would not substantially change the relative economic merit of the recommended and alternative plans.

13. On the basis of the study of alternatives described briefly in the foregoing paragraphs, it was determined that the recommended plan of improvement (plan C) was the most practicable plan for flood control on Elm Creek and tributaries for the city of Abilene.

CORPS OF ENGINEERS

U. S. ARMY

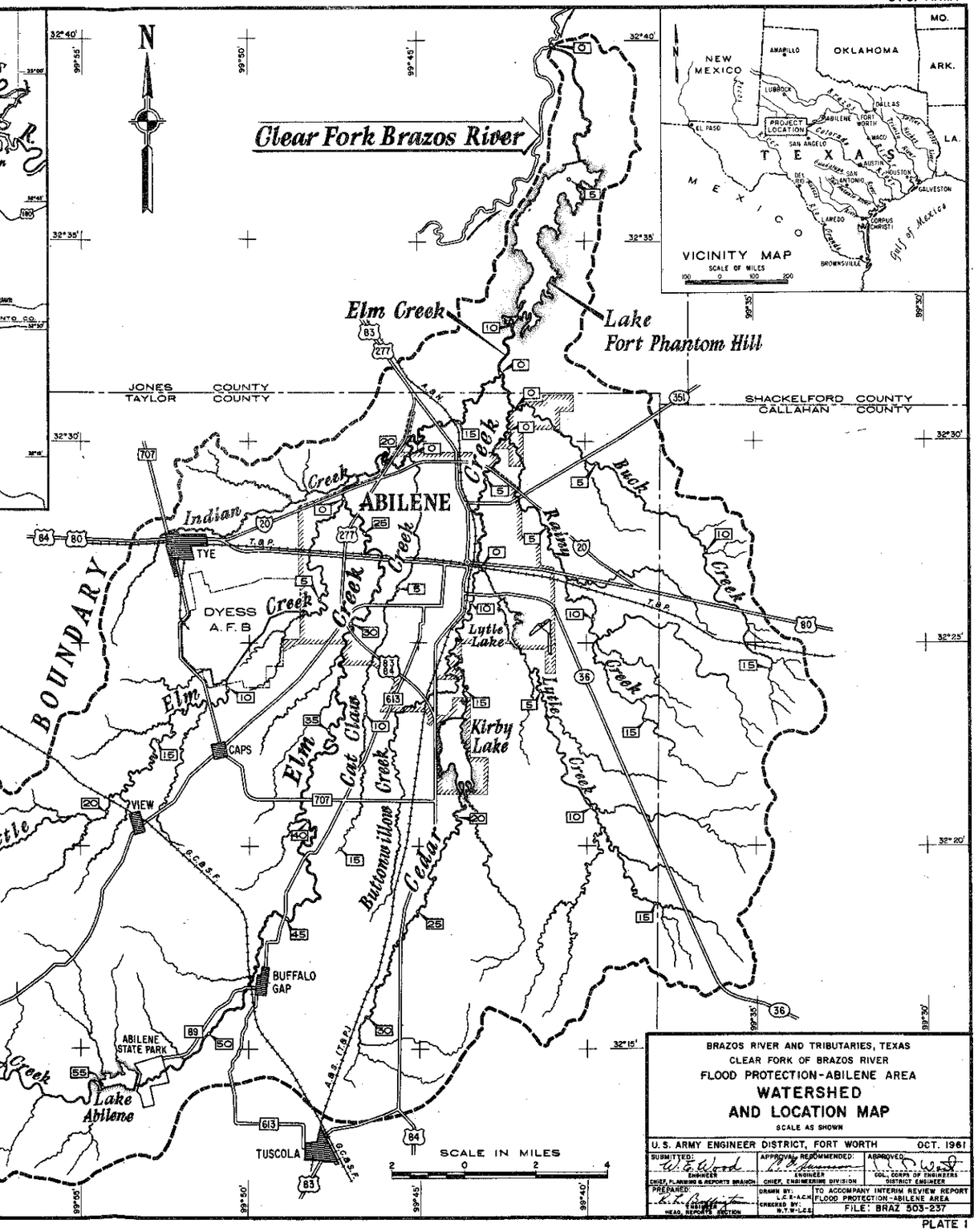


LOCATION MAP-ABILENE AND VICINITY

SCALE IN MILES 5 0 5 10 15 20

LEGEND

- (20) INTERSTATE HIGHWAY AND ROUTE NUMBER
- (217) U. S. HIGHWAY AND ROUTE NUMBER
- (351) STATE HIGHWAY AND ROUTE NUMBER
- (707) FARM TO MARKET HIGHWAY AND ROUTE NUMBER
- CITY BOUNDARY
- MILITARY BOUNDARY
- RAILROAD
- 5 MILES ABOVE MOUTH



BRAZOS RIVER AND TRIBUTARIES, TEXAS
CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION-ABILENE AREA
WATERSHED AND LOCATION MAP
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH OCT. 1961

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, REPORTS SECTION	DRAWN BY: L.Z.R.-A.C.H. CHECKED BY: W.T.W.-L.C.E.	TO ACCOMPANY INTERIM REVIEW REPORT FLOOD PROTECTION-ABILENE AREA FILE: BRAZ 503-237

PLATE 1

87780 O-62 (Face p. 92) No. 1

CORPS OF ENGINEERS

U. S. ARMY

LEGEND

- PROPOSED CHANNEL IMPROVEMENT AND RIGHT-OF-WAY LINE
- PROPOSED LEVEE
- STANDARD PROJECT FLOOD - EXISTING CONDITIONS
- STANDARD PROJECT FLOOD - IMPROVED CONDITIONS
- ONE HUNDRED YEAR FLOOD - EXISTING CONDITIONS
- FLOOD OF RECORD - EXISTING CONDITIONS
- 500+00 STATIONS IN FEET, ℄ IMPROVED CHANNEL
- 5 MILES ABOVE MOUTH
- 277 U.S. HIGHWAY AND ROUTE NUMBER
- 20 INTERSTATE HIGHWAY AND ROUTE NUMBER
- 36 STATE HIGHWAY AND ROUTE NUMBER
- 193 F.M. HIGHWAY AND ROUTE NUMBER
- RAILROAD
- CITY BOUNDARY

FLOOD OF RECORD AND ONE HUNDRED YEAR FLOOD WILL BE CONTAINED IN THE CHANNEL UNDER IMPROVED CONDITIONS.

NOTE
Abandoned portions of Existing Channel and low banks adjacent to Improved Channel to be filled.

Proposed Little Elm and Elm Creeks Channel Improvement

Proposed Diversion Channel and Cedar Creek Channel Improvement

Elm Creek Proposed Cleaning and Snagging

Cat Claw Creek Proposed Channel Improvement

Proposed Dike

Lake Fort Phantom Hill

Lytle Lake

Kirby Lake

DYESS AIR FORCE BASE

ABILENE

JONES CO.
TAYLOR CO.

Abilene and Northern (BURLINGTON)

T & P RY.

Abilene and Southern (T & P.)

BRAZOS RIVER AND TRIBUTARIES, TEXAS
CLEAR FORK OF BRAZOS RIVER
FLOOD PROTECTION - ABILENE AREA
PROPOSED PLAN OF IMPROVEMENT

SCALE OF FEET
2000 0 2000 4000

U.S. ARMY ENGINEER DISTRICT, FORT WORTH OCT. 1961

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
E. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, REPORTS SECTION	DRAWN BY: B.S.I. CHECKED BY: W.T.W.	TO ACCOMPANY INTERIM REVIEW REPORT FLOOD PROTECTION - ABILENE AREA FILE: BRAZ 503-237

PLATE 10