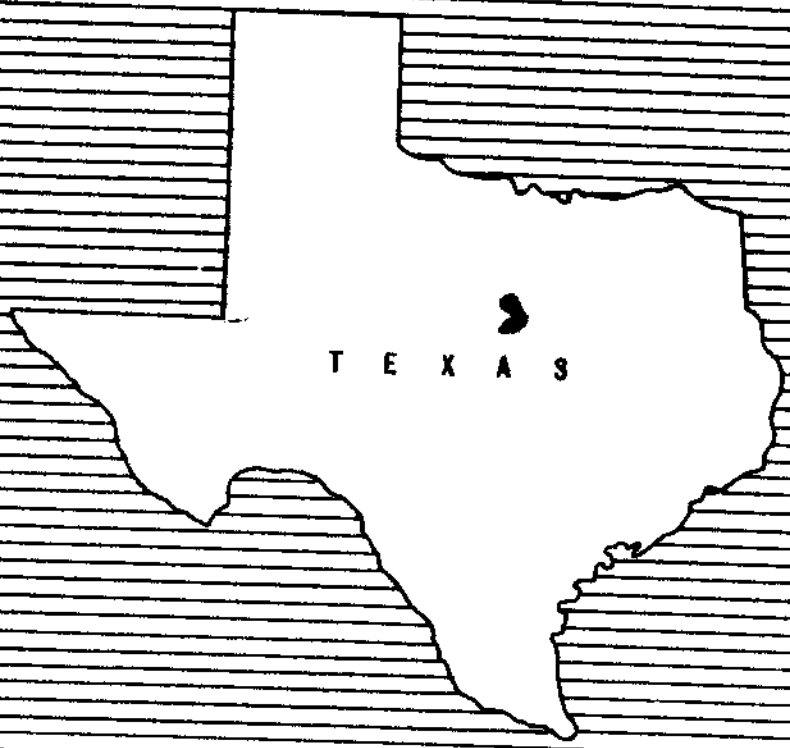
WORK PLAN

● For Watershed Protection and Flood Prevention

UPPER BOSQUE RIVER WATERSHED

ERATH, HAMILTON, AND BOSQUE COUNTIES, TEXAS



February 1963

WATERSHED WORK PLAN AGREEMENT

between the

Bosque Soil Conservation District
Local Organization

Hamilton-Coryell Soil Conservation District
Local Organization

Upper Leon Soil Conservation District
Local Organization

North Bosque Water Control and Improvement District

Erath County Commissioners Court
Local Organization

Hamilton County Commissioners Court

Bosque County Commissioners Court

State of Texas
(hereinafter referred to as the Sponsoring Local Organization)

and the

Soil Conservation Service
United States Department of Agriculture
(hereinafter referred to as the Service)

Whereas, application has heretofore been made to the Secretary of Agriculture by the Sponsoring Local Organization for sssistance in preparing a plan for works of improvement for the Upper Bosque River Watershed, State of Texas under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83d Congress; 68 Stat. 666), as amended; and

Whereas, the responsibility for administration of the Watershed Protection and Flood Prevention Act, as amended, has been assigned by the Secretary of Agriculture to the Service; and

Whereas, there has been developed through the cooperative efforts of the Sponsoring Local Organization and the Service a mutually satisfactory plan for works of improvement for the Upper Bosque River Watershed, State of Texas, hereinafter referred to as the watershed work plan, which plan is annexed to snd made a part of this agreement;

Now, therefore, in view of the foregoing considerations, the Sponsoring Local Organization and the Secretary of Agriculture, through the Service, hereby agree on the watershed work plan, and further agree that the works of improvement as set forth in said plan can be installed in about 8 years.

It is mutually agreed that in installing and operating and maintaining the works of improvement substantially in accordance with the terms, conditions, and stipulations provided for in the watershed work plan:

1. The Sponsoring Local Organization will acquire without cost to the Federal Government such land, easements, or rights-of-way as will be needed in connection with the works of improvement. (Estimated cost $ 306,996.)

2. The Sponsoring Local Organization will acquire or provide assurance that landowners or water users have acquired such water rights pursuant to State law as may be needed in the installation and operation of the works of improvement.

3. The percentages of construction costs of structural measures to be paid by the Sponsoring Local Organization and by the Service are as follows:

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Construction Cost (dollars)
28 Floodwater Retarding Structures	0	100	3,285,400

4. The percentages of the cost for installation services to be borne by the Sponsoring Local Organization and the Service are as follows:

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Installation Service Cost (dollars)
28 Floodwater Retarding Structures	0	100	707,616

5. The Sponsoring Local Organization will bear the costs of administering contracts. (Estimated cost $ 14,000 .)

6. The Sponsoring Local Organization will obtain agreements from owners of not less than 50% of the land above each reservoir and floodwater retarding structure that they will carry out conservation farm or ranch plans on their land.

7. The Sponsoring Local Organization will provide assistance to landowners and operators to assure the installation of the land treatment measures shown in the watershed work plan.

8. The Sponsoring Local Organization will encourage landowners and operators to operate and maintain the land treatment measures for the protection and improvement of the watershed.

9. The Sponsoring Local Organization will be responsible for the operation and maintenance of the structural works of improvement by actually performing the work or arranging for such work in accordance with agreements to be entered into prior to issuing invitations to bid for construction work.

10. The costs shown in this agreement represent preliminary estimates. In finally determining the costs to be borne by the parties hereto, the actual costs incurred in the installation of works of improvement will be used.

11. This agreement does not constitute a financial document to serve as a basis for the obligation of Federal funds, and financial and other assistance to be furnished by the Service in carrying out the watershed work plan is contingent on the appropriation of funds for this purpose.

    Where there is a Federal contribution to the construction cost of works of improvement, a separate agreement in connection with each construction contract will be entered into between the Service and the Sponsoring Local Organization prior to the issuance of the invitation to bid. Such agreement will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.

12. The watershed work plan may be amended or revised, and this agreement may be modified or terminated, only by mutual agreement of the parties hereto.

13. No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

Bosque Soil Conservation District
Local Organization

By Will C. Hafer
Will C. Hafer

Title Chairman

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Bosque Soil Conservation District
Local Organization

adopted at a meeting held on 5-17-63

Virgie R. Laughlin
(Secretary, Local Organization)
Virgie R. Laughlin

Date 5-17-63

Hamilton-Coryell Soil Conservation District
Local Organization

By O. C. King
O. C. King
Title Chairman

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Hamilton-Coryell Soil Conservation District
Local Organization

adopted at a meeting held on 4-9-63

Paul Hinson
(Secretary, Local Organization)
Paul Hinson
Date 5-20-63

Upper Leon Soil Conservation District
Local Organization

By C. M. McCain
C. M. McCain
Title Chairman

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Upper Leon Soil Conservation District
Local Organization

adopted at a meeting held on 5-10-63

H. W. Turney
(Secretary, Local Organization)
H. W. Turney
Date 5-17-63

North Bosque Water Control and Improvement District
Local Organization

By Fred McCleskey

Fred McCleskey

Title Chairman

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the North Bosque Water Control and Improvement District
Local Organization

adopted at a meeting held on 5-17-63

L B Howard

(Secretary, Local Organization)

L. B. Howard

Date 5-17-63

Erath County Commissioners Court
Local Organization

By Fred Allen

Fred Allen

Title Commissioner

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Erath County Commissioners Court
Local Organization

adopted at a meeting held on 5-13-63

Bill Croft

(~~Secretary~~, Local Organization)

Bill Croft, County Clerk

Date 5-17-63

Hamilton County Commissioners Court
Local Organization

By Fred Rainwater
Fred Rainwater
Title Commissioner

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Hamilton County Commissioners Court
Local Organization
adopted at a meeting held on 5-13-63

Vada Williams
(Secretary, Local Organization)
Vada Williams, County Clerk

Date 5-17-63

Bosque County Commissioners Court
Local Organization

By Jack M. Railsback
Jack M. Railsback
Title County Judge

Date 5-17-63

The signing of this agreement was authorized by a resolution of the governing body of the Bosque County Commissioners Court
Local Organization
adopted at a meeting held on 5-13-63

Jimmie B. Gill
(Secretary, Local Organization)
Jimmie B. Gill, County Clerk

Date 5-20-63

Soil Conservation Service
United States Department of Agriculture

By _____
Administrator

Date _____

WORK PLAN

FOR

WATERSHED PROTECTION AND FLOOD PREVENTION

UPPER BOSQUE RIVER WATERSHED
Erath, Hamilton, and Bosque Counties, Texas

Prepared Under the Authority of the Watershed Protection and Flood Prevention Act, (Public Law 566, 83rd Congress, 68 Stat. 666), as amended

Prepared By:

Bosque Soil Conservation District
(Sponsor)

Hamilton-Coryell Soil Conservation District
(Sponsor)

Upper Leon Soil Conservation District
(Sponsor)

North Bosque Water Control and Improvement District
(Sponsor)

Erath County Commissioners Court
(Sponsor)

Hamilton County Commissioners Court
(Sponsor)

Bosque County Commissioners Court
(Sponsor)

With Assistance By:

U. S. Department of Agriculture
Soil Conservation Service
February 1963

TABLE OF CONTENTS

	Page
WATERSHED WORK PLAN	1
SUMMARY OF PLAN	1
General Summary	1
Land Treatment Measures	1
Structural Measures	2
Damage and Benefits	2
Provisions for Financing Local Share of Installation Cost	3
Operation and Maintenance	3
DESCRIPTION OF WATERSHED	3
Physical Data	3
Economic Data	6
Land Treatment Data	7
WATERSHED PROBLEMS	7
Floodwater Damage	7
Sediment Damage	10
Erosion Damage	10
Problems Relating to Water Management	11
PROJECTS OF OTHER AGENCIES	12
BASIS FOR PROJECT FORMULATION	12
WORKS OF IMPROVEMENT TO BE INSTALLED	13
Land Treatment Measures	13
Structural Measures	15
EXPLANATION OF INSTALLATION COST	15
Schedule of Obligations	17
EFFECTS OF WORKS OF IMPROVEMENT	17
PROJECT BENEFITS	20
COMPARISON OF BENEFITS AND COSTS	23
PROJECT INSTALLATION	23
Land Treatment Measures	23
Structural Measures	24
FINANCING PROJECT INSTALLATION	25
PROVISIONS FOR OPERATION AND MAINTENANCE	27
Land Treatement Measures	27
Structural Measures	27

TABLE OF CONTENTS - Continued

	Page
TABLES	
Table 1 - Estimated Project Installation Cost	29
Table 2 - Estimated Structure Cost Distribution	30
Table 3 - Structure Data - Floodwater Retarding Structures	31-33
Table 4 - Annual Cost	34
Table 5 - Estimated Average Annual Flood Damage Reduction Benefits	35
Table 6 - Comparison of Benefits and Costs for Structural Measures	36
INVESTIGATIONS AND ANALYSES	37
Project Formulation	37
Land Treatment Measures	37
Structural Measures	37
Hydraulic and Hydrologic Investigations	40
Sedimentation Investigations	42
Sediment Source Studies	42
Flood Plain Sediment and Scour Damages	43
Reservoir Sedimentation	44
Geologic Investigations	44
Description of Problems	45
Further Investigations	47
Economic Investigations	47
Selection of Evaluation Reaches	47
Determination of Agricultural Damages	47
Determination of Nonagricultural Damage	48
Benefits from Reduction of Damage	48
Restoration of Former Productivity Benefits	49
Crop Distribution and Net Returns	50
Incidental Recreation Benefits	51
Secondary Benefits	51
Appraisal of Land and Easement Values	52
Details of Methodology	52
Fish and Wildlife Investigations	52
Forest Investigations	53
PLATES	
Plate 1 - Problem Location Map	54
Plate 2 - Section of a Typical Floodwater Retarding Structure	55
Plate 3 - Urban Benefit Area, Hico, Texas - 100 Year Frequency Flood	56
Plate 4 - Urban Benefit Area, Stephenville, Texas - 100 Year Frequency Flood	57
Plate 5 - Typical Floodwater Retarding Structure - General Plan and Profile	58
Plate 5A - Typical Floodwater Retarding Structure - Structure Plan and Section	59
Plate 6 - Project Map	60

WATERSHED WORK PLAN

UPPER BOSQUE RIVER WATERSHED
Erath, Hamilton, and Bosque Counties, Texas
February 1963

SUMMARY OF PLAN

General Summary

The work plan for watershed protection and flood prevention for Upper Bosque River watershed was prepared by the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts, the North Bosque Water Control and Improvement District, and the Commissioners Courts of Erath, Hamilton, and Bosque Counties, as sponsoring local organizations. Technical assistance was provided by the Soil Conservation Service of the United States Department of Agriculture.

The objectives of the project are to provide proper land use and treatment in the interest of soil and water conservation and flood protection for the flood plain lands along the North Bosque River and its tributaries and for the urban areas of Hico and Stephenville. The project as formulated meets these objectives. Sponsoring local organizations determined that no organized group was interested in including additional water storage for any agricultural or nonagricultural water management purposes.

The watershed covers an area of 368 square miles, or 235,520 acres, in Erath, Hamilton, and Bosque Counties, Texas. Approximately 23 percent of the watershed is cropland, 73 percent is rangeland or pasture, and 4 percent is in miscellaneous uses such as urban areas, roads, railroad rights-of-way, farmsteads, and stream channels.

There are no Federal lands in the watershed.

The work plan proposes installing, in an eight year period, a project for the protection and development of the watershed at a total estimated installation cost of $8,130,416. The share of the cost to be borne by Public Law 566 funds is $4,074,436. The share to be borne by other than Public Law 566 funds is $4,055,980. In addition, the local interests will bear the entire cost of operation and maintenance.

Land Treatment Measures

Landowners and operators will establish land treatment measures which will help accomplish the project objectives. Primarily these measures are those which contribute directly to watershed protection, flood prevention, and sediment control. The measures are listed in table 1.

The cost for land treatment measures is estimated to be $3,816,404, of which $3,734,984 will be borne by other than Public Law 566 funds. This amount

includes expected reimbursements from Agricultural Conservation Program Service and $93,600 to be spent by the Soil Conservation Service for technical assistance under its going program during the project installation period. The Public Law 566 share, consisting entirely of accelerated technical assistance is $81,420. The work plan includes only the land treatment that will be installed during the 8-year period.

Structural Measures

The structural measures included in the plan consist of 28 floodwater retarding structures having a total sediment storage and floodwater detention capacity of 58,930 acre-feet. The total cost of structural measures is $4,314,012, of which the local share is $320,996 and the Public Law 566 share is $3,993,016. The local share of the cost of structural measures consists of land, easements, and rights-of-way ($306,996) and administering contracts ($14,000). The 28 floodwater retarding structures will be installed during a 5-year period.

Damages and Benefits

The reduction in floodwater, sediment, flood plain erosion, and indirect damages will directly benefit owners and operators of approximately 190 farms and ranches in the watershed and owners and occupants of 140 residential and business units in Stephenville and Hico. In addition, processors of agricultural commodities and other businesses in the area will benefit from the project.

The estimated average annual floodwater, sediment, flood plain erosion, and indirect damages without the project total $233,405 at long-term price levels. With the proposed land treatment and structural measures installed, damages from these sources are estimated to be $65,708, a reduction of 72 percent.

The average annual primary benefits accruing to structural measures are $181,417, which are distributed as follows:

Damage reduction benefits	$161,235
Benefits from incidental recreation	8,830
Benefits outside project area (Damage reduction North Bosque River below watershed and sediment deposition reduction Waco Reservoir)	11,352

Secondary benefits of $17,080 annually will result from the project.

The ratio of the total annual project benefits ($198,497) to the average annual cost of structural measures ($137,094) is 1.4:1.

The total benefits from land treatment measures were not evaluated in monetary terms since experience has shown that these soil and water conservation measures produce benefits in excess of their costs.

Provisions for Financing Local Share of Installation Cost

The Commissioners Courts of Erath and Hamilton Counties have powers of taxation and eminent domain under applicable State laws. The Commissioners Courts of Erath and Hamilton Counties will furnish the funds for financing the share of those costs to be borne by local interest for structures located in the respective counties.

Operation and Maintenance

Land treatment measures for watershed protection will be operated and maintained by landowners or operators of farms and ranches on which the measures will be installed under agreement with the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts.

The Commissioners Courts of Erath and Hamilton Counties will be responsible for the operation and maintenance of the 28 floodwater retarding structures included in this plan. Funds for this purpose will come from existing county tax revenue which is available and adequate in each county. The estimated average annual cost of operation and maintenance of these structural measures is $5,344.

DESCRIPTION OF WATERSHED

Physical Data

The Upper Bosque River watershed, located in north central Texas, contains the source and is a large portion of the North Bosque River drainage area. Its total area of 235,520 acres (368.0 square miles) lies in central Erath County, the northern corner of Hamilton County, and the western corner of Bosque County.

The source of the North Bosque River is 12 miles west-northwest of Stephenville where two streams originate on opposite sides of a ridge. One, the north fork, flows eastward and then southeastward. The other, the south fork, flows southeastward and then eastward. The two streams join at the northern edge of Stephenville, becoming the North Bosque River. The North Bosque River flows through Stephenville and continues generally toward the southeast through the town of Hico. At Hico, it turns gradually toward the east and continues for about 10 miles to the lower end of the watershed (plate 6). The river flows into Waco Reservoir about 50 miles downstream from this point.

Green Creek is a major tributary entering the North Bosque River at Clairette. The Green Creek watershed has a watershed protection project installed under the authority of the Soil Conservation Act of 1935 (Public Law 46, 74th Congress).

Other major tributaries are Alarm Creek, Sims Creek, Indian Creek, Round Hole Branch, Spring Creek, Gilmore Creek, Honey Creek, Bailey Branch, and Fall Creek.

Elevations in the watershed range from approximately 1,550 feet above mean sea level along the divide to about 890 feet in the river channel at the lower end of the watershed. Cretaceous strata, occupying the entire watershed surface area, have greatly influenced the topography. The following tabulation shows, in descending order, the exposed strata within the watershed:

Group	Formation	Character
Washita	Duck Creek 1/	marly limestone
Fredericksburg	Kiamichi 1/	marl
Fredericksburg	Edwards 1/	limestone
Fredericksburg	Comanche Peak 1/	chalky limestone
Fredericksburg	Walnut 1/	clays, limestone seams, shell aggregates
Trinity	Paluxy 2/	sands, clays, siltstones, limy seams
Trinity	Glen Rose 1/	limestones, marls, clays, shales

1/ Grand Prairie Land Resource Area
2/ West Cross Timbers Land Resource Area

In the extreme lower end of the watershed, the divide is formed by a very pronounced westward extending finger of resistant Comanche Peak and Edwards limestones topped with small outliers of Kiamichi marl and Duck Creek limestone. This accounts for only two percent of the watershed area.

Remnants of the Walnut formation exist as moderate to steeply sloping ridges and divides in the upper portion of the watershed where an abundance of limestone seams offer resistance to erosion. In the lower portion of the watershed clays become dominant in the Walnut formation causing very gently rolling topography. The Walnut outcrop occupies 20 percent of the watershed area.

The outcrop of the Paluxy formation occupies 55 percent of the watershed. The sands, clays, and siltstones, offering little resistance to erosion, form moderately rolling to nearly level topography.

The Glen Rose, which is the lowermost exposed formation in the watershed, underlies the Paluxy. Its outcrop covers 23 percent of the watershed along and adjacent to the main stem and larger tributaries. The slower erosion rates of hard limestones compared to that of soft interbedded marls, shales, and clays have resulted in moderate to steep valley slopes of "staircase" topography.

The broad flood plain is made up of deep fertile alluvium which overlies a large portion of the Glen Rose and Paluxy formations.

Surface soils of the West Cross Timbers Land Resource Area occupy about 55 percent of the watershed. These soils are mostly fine sandy loams or loamy fine sands, six to thirty inches thick. Subsoils are sandy clays and sandy clay loams ranging from slowly to moderately permeable. In some areas, loose blow sands are three to five feet thick. Soils of the Grand Prairie Land Resource Area, covering the remaining 45 percent of the watershed, are mostly calcareous clays and clay loams ranging from slowly to moderately permeable and from deep to very shallow and stony. Soil series within the watershed are primarily Winthorst, Travis, Stephenville, Nimrod, and Bastrop in the West Cross Timbers Land Resource Area and Denton, Tarrant, San Saba, Krum, Brackett, Crawford, Lewisville, Gowen, and Catalpa in the Grand Prairie Land Resource Area.

The hydrologic cover condition, ranging from good to poor, is classed mostly as fair. The natural vegetal cover of the West Cross Timbers is generally a combination of post oak and blackjack oak savannah. The cover of the Grand Prairie varies from true prairie with less than five percent tree canopy to live oak savannah with 20 percent canopy. Large pecans and elms are abundant in the bottomland. Some of the climax grasses are little bluestem, Indiangrass, big bluestem, switchgrass, Canada wildrye, and sand lovegrass. Increasers include silver bluestem, sideoats grama, hairy dropseed, Texas wintergrass, and hairy grama. Wild alfalfa, dotted gayfeather, blacksampson, perennial legumes, and scurfpeas are some of the climax forbs. Vegetation which invades following overuse of rangeland includes threeawns, western ragweed, Texas grama, hairy tridens, red grama, windmillgrass, sand dropseed, nightshades, mesquite, post oak, blackjack oak, juniper, sumac, and pricklypear. Range sites within the watershed are Sandy Loam, Sandy, Deep Sandy, Bottomland, Rolling Prairie, Deep Upland, Rocky Prairie, Adobe, Rocky Upland, Redland, and Very Shallow.

The over-all land use in the watershed is as follows:

Land Use	Acres	Percent
Cropland	53,883	23
Pasture	13,553	6
Rangeland	158,752	67
Miscellaneous 1/	9,332	4
Total	235,520	100

1/ Includes roads, highways, railroad rights-of-way, urban areas, farmsteads, stream channels, etc.

The climate is warm and subhumid. The mean monthly temperature ranges from 45 degrees Fahrenheit in January to 83 degrees in July. The normal frost-free period of 236 days extends from March 23 through November 14. The

average annual rainfall is 30.8 inches. Precipitation is fairly well distributed throughout the year but is heaviest during April, May, June and September.

Water for livestock and rural domestic use is obtained from wells and surface ponds, but during periods of prolonged drought this supply is unreliable. Wells are the source of municipal water for the cities of Stephenville and Hico.

Economic Data

The economy of the watershed is dependent largely on its agricultural production. Until about 1940, the production and sale of cash crops such as cotton, corn, oats, and peanuts was the primary source of farm income. Since then there has been a marked increase in production of livestock, dairy and poultry products. Production and sale of cash crops have declined greatly and considerable acreage once devoted to crop production is now utilized for improved pasture and forage crops.

The average size farm in the watershed is approximately 265 acres. This reflects a significant increase in recent years. In Erath County, for instance, the average size farm increased almost 90 acres between 1949 and 1959. The majority of the farms are owner-operated and the average value of land and buildings per farm is approximately $20,600 (1959 agricultural census). The estimated current value of flood plain land is $150 to $225 per acre. Upland ranges from $60 to $150 per acre.

The population of the three counties in which the watershed lies declined about 13 percent between 1950 and 1960. The decreases ranged from almost 9 percent in Bosque County to slightly over 20 percent in Hamilton County. Most of the decline was in the rural population. The number of farms in Erath County, for example, decreased from 2,163 in 1949 to 1,617 in 1959. The population of Stephenville and Hico remained almost stationary. A gain of 204 at Stephenville during the decade was almost offset by decrease of 194 people in Hico.

Stephenville, population 7,359, and Hico, population 1,020, are the largest towns in the watershed. Both of these centers provide market and supply services for the poultry industry. Stephenville provides market services to the surrounding dairy industry with a cheese plant which processes over 7,000,000 pounds of milk annually. Tarleton State College and the West Cross Timbers Agricultural Experiment Station are located at Stephenville and have had a pronounced effect on agricultural development of the area. Huckabay, Lingleville, and Selden are small communities in the watershed. These rural centers provide limited marketing and supply services.

Livestock produced in the watershed is marketed at Stephenville, Hico, Dublin, Hamilton, and Fort Worth. Most of the whole milk produced in the area is shipped by tank trucks to Fort Worth and Abilene.

The watershed is served adequately by approximately 450 miles of Federal, State, and county roads, of which about 155 are hard surfaced. In addition, there are numerous private farm and ranch roads. Adequate rail facilities are provided by the Gulf Colorado and Santa Fe Railroad with loading facilities at Stephenville and by the Missouri Kansas and Texas Railroad with loading facilities at Hico.

Land Treatment Data

Soil Conservation Service work units at Stephenville, Dublin, Meridian, and Hamilton are assisting the Bosque, Upper Leon, and Hamilton-Coryell Soil Conservation Districts. A total of 859 farm and ranch units are operating in the watershed. The work units have assisted soil conservation district cooperators in preparing 649 soil and water conservation plans and have given technical assistance in establishing and maintaining planned measures. Current revision is needed on 173 conservation plans. Satisfactory soil surveys have been made on 198,286 acres, leaving 37,234 acres needing additional soil surveys. Approximately 45 percent of needed land treatment practices for the 226,188 acres of agricultural land have been applied.

WATERSHED PROBLEMS

Floodwater Damage

An estimated 13,211 acres of the watershed, excluding stream channels, is flood plain (plate 1). As described herein, the flood plain is the area that will be inundated by the runoff from the largest storm considered in the 20-year series used for agricultural evaluation. The runoff from this storm approximates the 100-year frequency in the upper part of the watershed and diminishes to approximately a 25-year frequency at the lower end of the watershed. Because of the shape of the flood plain, there is very little variation in area inundated by floods exceeding the 25-year frequency except in the urban areas of Stephenville and Hico.

Flooding occurs frequently in the agricultural flood plain and causes severe damage to growing crops and other agricultural properties. In addition, damage to flood plain lands from deposition of sediment and flood plain erosion has resulted in reductions in crop yields and forced many operators to reduce the intensity of farming operations in areas most severely affected. The significance of flood damage is increased below Stepenville where the farms and ranches adjacent to the Bosque River have fertile flood plain soil and the upland is unsuited for cultivation. Thus, nearly all land suitable for cultivation is subject to frequent flood damage.

In the urban areas of Stephenville and Hico, minor damage occurs almost annually to low lying park areas and crossings. In Stephenville, floods causing in excess of $3,000 damage occur on the average of every four or five years. In Hico, damage in excess of $7,500 has occurred on the average of about every three years.

The most damaging floods in recent years occurred May 23, 1952, and May 18, 1955. The flood of 1952 was of greater magnitude in the lower portion of the watershed, and the flood of 1955 was of greater magnitude in the upper portion. Both floods inundated almost the entire agricultural flood plain. Damage to newly planted row crops and maturing small grain was extensive. Erosion of flood plain land and damage from sediment deposition was severe. Fence and livestock losses were heavy, and all roads and railroads in the flood plain were damaged heavily.

In Stephenville the flood of 1955 caused damage to about 45 homes, 10 business establishments, utilities, streets, and parks. Most of the homes and businesses were flooded to depths ranging from a few inches to 4 feet. Damages were estimated to be $103,842.

In Hico the flood of 1952 caused damage to about 40 homes, 8 business establishments, utilities, streets, and the park. About 28 of the homes were flooded to depths up to 3 feet deep. Business establishments were flooded to depths up to 5 feet deep. Damages from this flood were estimated at $85,820.

No lives were lost from either of these floods.

Other recent floods that caused significant damage to urban property in both Stephenville and Hico occurred in 1949, 1956, 1957, and 1958.

Rainfall during the 20-year evaluation period, 1941 through 1960, is considered representative of normal rainfall in the area. During this period there were 18 major floods that inundated more than half the agricultural flood plain and 49 minor floods that inundated less than half the flood plain. Thirteen of the major floods and 37 of the minor floods occurred during the spring, summer, or early fall months when most of the crops are highly susceptable to damage.

Based on the floods experienced during the period studied (20 years in agricultural areas) and those expected to occur in urban areas, including floods up to a 100-year frequency, the total direct floodwater damage is estimated to average $177,376 annually at long-term price levels (table 5). Of this amount, $89,574 is crop and pasture damage; $59,352 is other agricultural damage; $10,031 is nonagricultural damage to roads, bridges, and railroads; $17,240 is damage to urban properties; and $1,179 is damage to other nonagricultural developments.

Indirect damages such as interruption of both highway and rail traffic, losses sustained by businesses in the area, temporary dislocation of persons from homes and work, re-routing of school bus and mail routes, and similar losses are estimated to average $22,889 annually.

Flood damage in Stephenville as a result of flood of May 18-19, 1955. Water had been two feet deep in house during the night.

Floodwater in Stephenville Park on morning after flood of May 18-19, 1955. Water had been 3.5 feet higher during the night.

Sediment Damage

Sediment damage is moderate to severe. The most damaging sediment consists of sands which originate in the West Cross Timbers Land Resource Area and tends to be deposited close to their point of origin. Most fine textured sediments are transported farther downstream and cause less damage. Sandy deposits, reducing channel capacity and threatening bridges, are evident northwest of Stephenville on the north fork. Overbank deposits, ranging from sandy clays to coarse sands, have reduced the productive capacity of an estimated 2,194 acres of flood plain land from 10 to 60 percent. The following tabulation shows this damage by evaluation reaches:

Area Damaged by Overbank Deposition of Sediment

Evaluation Reach (Plate 1)	Percent Damage 10	20	30	40	50	60	Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
A	57	235	145	0	0	0	437
B	54	60	6	0	0	0	120
C	0	125	62	0	0	11	198
D	0	0	0	0	0	0	0
E	18	347	0	0	8	0	373
F	0	22	175	35	0	0	232
G	140	12	120	52	0	0	324
H	9	0	6	3	0	0	18
I	0	0	17	0	0	0	17
J	0	0	16	0	0	0	16
K	24	42	141	112	0	0	319
L	5	41	94	0	0	0	140
Total	307	884	782	202	8	11	2,194

The average annual monetary value of this damage is estimated to be $13,220 at long-term price levels (table 5).

Annual sediment production rates range from 1.1 acre-feet per square mile in the West Cross Timbers to 0.5 acre-foot in the Grand Prairie. Although the West Cross Timbers is a major source of sandy sediment, the Upper Bosque River watershed contributes only a minor amount of the total sediment deposited in Waco Reservoir. The long distance from the watershed to the reservoir and the coarse texture of sediment prevent large volumes of Upper Bosque sediment from reaching Waco Reservoir. The annual loss of storage capacity in the reservoir from sediment originating in the Upper Bosque River watershed is estimated to average 157 acre-feet.

Erosion Damage

The estimated average annual rate of gross erosion is 2.35 acre-feet per square mile. Of this, sheet erosion accounts for 77 percent, gully and streambank erosion 5 percent, and flood plain scour 18 percent.

Annual upland erosion rates range from 2.6 acre-feet per square mile in the West Cross Timbers to 1.0 acre-foot per square mile in the Grand Prairie. Loss of valuable topsoil by sheet erosion has been severe in the West Cross Timbers and in some areas of overused grassland in the Grand Prairie. Severe gullying is occurring in small isolated areas of the West Cross Timbers. The most significant of these is an area of about 240 acres located in the drainage area of the north fork above Stephenville. This area has several active gullies which are a source of high sediment production. In general, gradual healing of gullied areas is occurring. Good conservation practices have been very effective in reducing gully erosion and the movement of damaging sediment downstream.

Flood plain erosion is moderate to severe. Most of the damaged areas range from broad sheet scour depressions to channels four to five feet deep. There are some small areas of severe damage with narrow channels 10 to 12 feet deep. It is estimated that the productive capacity of 3,723 acres has been reduced from 10 to 100 percent by scour. The following tabulation shows flood plain erosion damage by evaluation reaches:

Area Damaged by Flood Plain Scour

Evaluation Reach (Plate 1)	Percent Damage 10	20	30	40	50	100	Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
A	184	285	155	32	0	2	658
B	133	35	13	8	0	0	189
C	111	125	0	0	0	0	236
D	0	0	0	0	0	0	0
E	246	187	91	0	10	0	534
F	145	601	6	0	3	0	755
G	309	86	47	55	0	0	497
H	17	5	2	3	0	0	27
I	0	28	0	0	0	0	28
J	26	18	0	0	0	0	44
K	150	98	27	7	7	0	289
L	389	55	10	12	0	0	466
Total	1,710	1,523	351	117	20	2	3,723

The average annual monetary value of this damage is estimated to be $19,920 at long-term price levels (table 5).

Problems Relating to Water Management

Surface drainage of agricultural land is not a problem and irrigation activity is of minor importance in the watershed.

The city of Stephenville obtains its water from wells. This supply is adequate for present and immediate future needs. However, the city has been making

investigations to determine possible sources of surface water to meet long-range future needs.

PROJECTS OF OTHER AGENCIES

There are no existing or proposed water resource development projects of any other agency within the watershed.

The works of improvement included in this plan will have no known detrimental effects on any existing or proposed downstream works of improvement. Conversely, the project will complement the Waco Reservoir by decreasing sediment being delivered from this watershed.

BASIS FOR PROJECT FORMULATION

An initial study was made by representatives of the Soil Conservation Service and sponsoring local organizations to determine watershed problems and possible solutions.

Meetings were held with the sponsoring local organizations to discuss existing problems and to formulate project objectives. Flood prevention was the first objective to be considered. The city of Stephenville wished to consider the feasibility of obtaining a supplemental municipal water supply from a multiple-purpose structure. In addition, the sponsoring local organizations considered the inclusion of additional storage in one or more floodwater retarding structures for agricultural or nonagricultural water management purposes.

In addition to expressing the desire for establishment of a complete program for soil and water conservation on the watershed, the following specific objectives were agreed to:

1. Establish land treatment measures which contribute directly to watershed protection and flood prevention (table 1).

2. Attain a reduction of 65 to 70 percent in average annual flood damages to agricultural flood plain lands, with a minimum of about 60 percent reduction in any one agricultural reach.

3. Attain a reduction of 85 to 90 percent in average annual flood damages in Hico and Stephenville.

Investigations were made of the possibility of incorporating water storage for municipal use for Stephenville. The city of Stephenville, with the assistance of consultant engineers, made a thorough study of possible multiple-purpose structure locations, the area contributing runoff, and probable water yields. From these investigations, it was determined that storage of municipal water in a multiple-purpose structure would not be economically feasible because of inadequate water yield and distance to existing distribution system.

After full consideration, neither the sponsoring local organizations nor any other organized group wished to incorporate storage for other water management purpose.

In selecting sites for floodwater retarding structures, consideration was given to locations which would provide the agreed upon level of protection to areas subject to damage. The size, number, design, and cost of the structures was influenced to a high degree by the physical, topographic, and geologic conditions in the watershed.

The recommended system of structural measures meets the project objectives in providing the desired level of protection to agricultural and urban areas at least cost. The floodwater retarding structures also provide incidental recreation benefits at no additional cost.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

An effective conservation program based upon the use of each acre of agricultural land within its capabilities and its treatment in accordance with its needs for protection and improvement, such as is now being carried out by the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts, is necessary for a sound watershed protection and flood prevention program on the watershed. Basic to reaching this objective is the establishment and maintenance of all applicable soil and water conservation and plant management practices essential to proper land use. Emphasis will be placed on the establishment of land treatment practices which have a measurable effect on the reduction of floodwater, sediment, and erosion damages.

Of the total watershed area of 235,520 acres, 104,180 lie above planned floodwater retarding structures. Land treatment measures will help the structural measures to function more efficiently by reducing runoff and sediment. They are the only measures planned for the remaining upland area. Land treatment measures on the agricultural land within the 12,967 acres of the flood plain that will not be inundated by pools of the planned floodwater retarding structures also are important in reducing floodwater, sediment, and erosion damages.

The amounts and estimated costs of the measures that will be installed by landowners and operators during the 8-year installation period are shown in table 1. Farmers and ranchers will continue to install and maintain land treatment measures needed in the watershed after the installation period.

Land treatment measures decrease erosion and sediment production rates by providing improved soil-cover conditions. These measures include conservation cropping systems, cover and green manure crops, and crop residue use for cropland. Proper use and pasture planting are included to establish good cover on grassland and formerly cultivated land. Also included are

Deferred grazing of rangeland improves grass stands and is effective in slowing runoff and reducing soil erosion.

Cover crops on cultivated land are effective in improving soil conditions which allow rainfall to soak into the soil at a more rapid rate.

proper range use, deferred grazing, range seeding, and brush control to improve grass cover on rangeland. Construction of farm ponds will provide adequate watering places for livestock and encourage uniform distribution of grazing. These measures effectively improve soil conditions which allow rainfall to infiltrate the soil at a more rapid rate.

In addition to the soil improving and cover measures, land treatment includes contour farming, gradient terraces, diversions, and grassed waterways, all of which have a measurable effect in reducing peak discharge by slowing runoff water from fields and in reducing erosion damage and sediment production.

Structural Measures

A system of 28 floodwater retarding structures will be installed to afford the needed protection to flood plain lands and to urban areas in Hico and Stephenville at an estimated installation cost of $4,314,012.

Plate 2 shows a section of a typical floodwater retarding structure.

The location of structural measures is shown on the Project Map (plate 6).

This system of structures will detain runoff from approximately 44 percent of the watershed area included in this plan and about 38 percent of the total drainage area, including the uncontrolled portion of Green Creek watershed. The 28 floodwater retarding structures will have a total floodwater detention capacity of 45,600 acre-feet and will detain an average of 5.25 inches of runoff from the watershed area above them.

Sufficient detention storage can be developed at all structure sites to make possible the use of vegetative or natural rock spillways, thereby effecting a substantial reduction in cost over concrete or similar types of spillways.

All applicable State water laws will be complied with in design and construction of the planned structural measures.

Refer to tables 1, 2, and 3 for details on quantities, costs, and design features of the structural measures.

EXPLANATION OF INSTALLATION COST

Public Law 566 funds will provide technical assistance in the amount of $81,420 during the 8-year installation period to accelerate the installation of the land treatment measures included in the plan for watershed protection. This amount includes $2,500 for completion of needed standard soil surveys in Hamilton County. These Public Law 566 funds will be in addition to $93,600 of Public Law 46 funds provided under the going program. Local interests will install land treatment measures at an estimated cost of $3,641,384,

which includes reimbursements from Agricultural Conservation Program Service funds based on present program criteria (table 1). The costs are based on present prices being paid by landowners or operators to establish the individual measures in the area. The number of land treatment measures to be applied and the unit cost of each measure was estimated by the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts.

The required local costs for structural measures consisting of the value of land easements ($266,921); change in utilities ($16,700) and roads ($15,500); removal and relocation of improvements ($2,700); legal fees ($5,175); and administration of contracts ($14,000) are estimated at $320,996. The Board of Directors of the North Bosque Water Control and Improvement District provided estimates of these costs.

Secondary costs associated with reduced agricultural production within pool areas were calculated. However, it was found that the appraised value of land easements exceeded both these costs and the value of production lost.

The entire construction cost for structural measures, amounting to $3,285,400, will be borne by Public Law 566 funds. In addition, the installation services cost of $707,616 will be a Public Law 566 expense. This is a total Public Law 566 cost of $3,993,016 for the installation of structural measures.

Construction costs include the engineers' estimate and contingencies. The engineers' estimates were based on the unit costs of floodwater retarding structures in similar areas, modified by special conditions inherent to each individual site location. They include such items as rock excavation, permeable foundation conditions, and site preparation. Geologic investigations consisted of surface observations, seismic investigations, and hand auger borings. More detailed geologic investigations will be needed before construction begins. Ten percent of the engineers' estimate was added as a contingency to provide funds for unpredictable construction costs.

Installation services include engineering and administrative costs. These estimates were based on an analysis of previous work in similar areas.

The estimated schedule of obligations for the 8-year installation period covering installation of both land treatment and structural measures is as follows:

Schedule of Obligations

Fiscal Year	Measures	Public Law 566 Funds (dollars)	Other Funds (dollars)	Total (dollars)
1	Sites 1, 2, 3, 4, 5, 6	766,365	84,395	850,760
	Land Treatment	12,365	466,873	479,238
2	Sites 7, 8, 9, 10, 11, 12	774,436	100,109	874,545
	Land Treatment	9,865	466,873	476,738
3	Sites 13, 14, 15, 16, 17	830,709	69,096	899,805
	Land Treatment	9,865	466,873	476,738
4	Sites 18, 19, 20, 21, 22, 23	719,505	29,075	748,580
	Land Treatment	9,865	466,873	476,738
5	Sites 24, 25, 26, 27, 28	902,001	38,321	940,322
	Land Treatment	9,865	466,873	476,738
6	Land Treatment	9,865	466,873	476,738
7	Land Treatment	9,865	466,873	476,738
8	Land Treatment	9,865	466,873	476,738
	Total	4,074,436	4,055,980	8,130,416

This schedule may be adjusted from year to year on the basis of any significant changes in the plan found to be mutually desired, and in the light of appropriations and accomplishments actually made.

EFFECTS OF WORKS OF IMPROVEMENT

This project will directly benefit the owners and operators of approximately 190 farms and ranches in the watershed and the owners and occupants of 140 residential and business units in Hico and Stephenville. In addition, the owners and operators of all farms and ranches along the Bosque River down to the Waco Reservoir will be directly benefited by the project.

The combined program of land treatment and structural measures will prevent flood damage from 28 of the 67 floods such as occurred in the watershed from 1941 through 1960. Of the 18 major floods that inundated more than half of the flood plain, 13 would be reduced to minor floods inundating less than half the flood plain. Average annual flooding will be reduced from 11,510 acres to 4,486 acres, a reduction of 61 percent. This includes the flooding on the flood plain of Honey Creek for which no structural measures are planned.

Under present conditions 12,967 acres of flood plain, excluding the pool areas of the planned floodwater retarding structures, have been inundated by runoff from the largest storm considered during the 20-year period, 1941-1960. It is estimated that the area inundated by a similar flood would be reduced to 10,899 acres following the installation of the planned land treatment and structural measures.

The area on which sediment damage from overbank deposition will occur is expected to be reduced from 2,194 acres to 768 acres, a reduction of 65 percent.

The area on which flood plain scour damage will occur is expected to be reduced from 3,723 acres to 1,489 acres, a reduction of 60 percent.

Land treatment measures will reduce the average annual gross erosion from 866 to 733 acre-feet per year. Sediment yield from the watershed will be reduced from 196 to 112 acre-feet annually as a result of the combined program of land treatment and structural measures.

Reduction in area inundated varies with respect to location within the watershed. The general locations of the areas benefited from reduction in flooding with the project installed are presented in the following tabulation:

Average Annual Area Inundated 1/

Evaluation Reach (Plate 1)	General Location	Without Project (acres)	With Project (acres)	Reduction (percent)
A	Bottom of Watershed to Honey Creek	1,522	758	50
B	Honey Creek	303	277	9
C	Honey Creek to Hico	704	326	54
D	Hico Area	82	25	70
E	Hico to Green Creek	2,285	1,023	55
F	Green Creek to Alarm Creek	1,854	553	70
G	Alarm Creek to Stephenville	1,391	662	52
H	Stephenville Area	167	33	80
I	Dry Branch and Tributaries	189	49	74
J	Stephenville to confluence of North and South Forks	121	53	56
K	North Fork above Stephenville	1,427	467	67
L	South Fork above Stephenville	1,465	260	82
Total		11,510	4,486 2/	61

1/ Exclusive of area of flood plain inundated by floodwater retarding structure pools.

2/ Includes area subject to overflow on Honey Creek for which no structural control is planned.

Outlines of urban areas inundated by a 100-year frequency flood in Hico and Stephenville are shown for without and with project conditions on plates 3 and 4. Although some areas in Hico will be inundated by large floods, even with the project installed, physical damage to property will be greatly diminished. The number of homes flooded from a flood similar to 1952 will be reduced from 28 to 2. Significant flooding would be eliminated from 3 of the 8 business establishments flooded. Elevation of flood water would be reduced 2.7 feet.

The number of homes flooded from a 100-year frequency event will be reduced from about 40 to 11 with maximum depth of flooding being reduced from about 4.5 feet to less than 2 feet. All 8 business establishments would still be subject to flooding, but to a lesser depth.

In Stephenville all flooding from a 100-year frequency flood will be elimimated except in low-lying park areas, low water crossings, and undeveloped areas.

Owners and operators of flood plain land say that if adequate flood protection is provided, particularly through a reduction of sediment deposition and flood plain scour, they will restore land now idle or in low value crops to production of higher value crops. It is estimated that after the project is installed, 874 acres of flood plain land will be restored to a higher value use. All of this land was in production of higher value crops until recent years but is now either in production of low value crops or idle because of excessive flood damage.

Analysis of information collected indicated that no significant changes in use of flood plain land in Hico or Stephenville would result from the installation of the project.

Only 244 acres of flood plain will be involved in the sediment and detention pools of planned structures. A total of 125 acres of flood plain land and 1,517 acres of upland in the sediment pools will be retired from agricultural production. Of this, only 13 acres of flood plain and 169 acres of upland is cropland.

Additional incidental recreational benefits will result from the installation of the 28 floodwater retarding structures included in this plan. Sediment pool elevations of these structures are at the 50-year sediment storage level or 200 acre-feet capacity, whichever is less. The sediment pools cover 874 surface acres. These pools are located within easy driving distance of all inhabitants of Erath, Hamilton, and Bosque Counties and will serve as outdoor recreational facilities for fishing, swimming, hunting, and boating. Judging from the experience to date on Green Creek, an adjoining watershed, it appears that the pools in most of the structures will be open to the general public or to organized groups. Access to some will be free. At others a small fee will be charged. It is conservatively estimated that these pool areas will attract 13,600 visitors annually.

Benefits will accrue to the structural measures in the watershed from reduction of floodwater damages on the 20,913 acres of flood plain land on the mainstem of the North Bosque River between the watershed and Waco Reservoir. Between the watershed and Clifton, there are 13,560 acres of flood plain. This project will control an average of 28 percent of the drainage area contributing to this reach. Between Clifton and Waco Reservoir there are 7,353 acres of flood plain. An average of 16 percent of the drainage area contributing to this reach will be controlled by the floodwater retarding structures to be installed in this watershed. In addition, the proposed project will reduce sediment deposition in Waco Reservoir by 67 acre-feet annually. Of this amount, 45 acre-feet is attributable to the 28 planned floodwater retarding structures.

Secondary benefits stemming from the project will accrue to trade area businesses through increased net income from sales and services resulting from the increased production as a result of project installation. Benefits induced by the project will result from the expenditures associated with incidental recreation and from the increased cost of production of the additional commodities produced.

PROJECT BENEFITS

The estimated average annual monetary floodwater, sediment, erosion, and indirect damages (table 5) within the watershed will be reduced from $233,405 to $65,708 by the proposed project. This is a reduction of 72 percent, 96 percent of which will result from the system of floodwater retarding structures.

Reduction in monetary flood damages vary with respect to locations within the watershed. The following tabulations show the general locations of damage reduction benefits attributed to the combined program of land treatment and structural measures:

Evaluation Reach (Plate 1)	General Location	Average Annual Damage: Without Project (dollars)	With Project (dollars)	Reduction (percent)
A	Bottom of Watershed to Honey Creek	22,253	9,074	59
B	Honey Creek	4,186	3,756	10
C	Honey Creek to Hico	14,210	5,085	64
D	Hico Area	16,148	2,291	86
E	Hico to Green Creek	46,473	15,934	66
F	Green Creek to Alarm Creek	35,585	8,923	75

Average Annual Damage - Continued

Evaluation Reach (Plate 1)	General Location	Without Project (dollars)	With Project (dollars)	Reduction (percent)
G	Alarm Creek to Stephenville	30,003	11,636	61
H	Stephenville Area	5,843	435	93
I	Dry Branch and Tributaries	2,796	133	95
J	Stephenville to confluence of North and South Forks	2,003	596	70
K	North Fork above Stephenville	22,638	5,031	78
L	South Fork above Stephenville	21,199	2,814	87
Total		223,337 1/	65,708 2/	71

1/ Exclusive of damage considered under restoration of former productivity ($10,068).

2/ Includes damages on Honey Creek for which no structural control is planned.

Direct Monetary Floodwater Damage to Urban Property

Location (Plate 1)	Average Recurrence Interval: 2 Year Without Project (dollars)	2 Year With Project (dollars)	10 Year Without Project (dollars)	10 Year With Project (dollars)	25 Year Without Project (dollars)	25 Year With Project (dollars)	100 Year Without Project (dollars)	100 Year With Project (dollars)
Hico	1,405	0	40,750	3,825	62,230	13,825	104,950	42,625
Stephenville	1,700	0	4,200	1,200	10,350	1,600	90,063	2,550
Total	3,105	0	44,950	5,025	72,580	15,425	195,013	45,175

In Stephenville all damage remaining after installation of the project will be limited to park areas and low water street crossings.

In Hico much of the development is at a low elevation in relation to bank-full elevation of the river. Because of the large contributing drainage area at this point and the relatively low remaining monetary damage, it is not feasible to provide a higher degree of damage reduction. Because of the variation in

the type of property subject to floodwater damage the following tabulation is presented:

Direct Monetary Floodwater Damage in Hico by Types of Property

Type	Average Recurrence Interval							
	2 Year		10 Year		25 Year		100 Year	
	Without Project	With Project	Without Project	With Project	Without Project	With Project	Without Project	With Project
	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Residential	150	0	10,000	350	21,750	1,500	51,125	10,925
Business	1,150	0	25,450	3,350	33,200	11,050	43,800	26,200
Other 1/	105	0	5,300	125	7,280	1,275	10,025	5,500
Total	1,405	0	40,750	3,825	62,230	13,825	104,950	42,625

1/ Park, streets, utilities, etc.

It is estimated that the net increase in income from restoration of former productivity will amount to $10,068 (at long-term price levels) annually. This loss from the original production has been included in the crop and pasture damage and its restoration a benefit in table 5.

The annual net monetary value of the incidental recreational benefits from use of the sediment pools of the floodwater retarding structures is estimated to be $8,830.

Benefits averaging $9,044 annually will accrue to the planned structural measures from reduction of floodwater damages on the mainstem of the North Bosque River below the watershed. The monetary value of the reduction of sediment deposition in Waco Reservoir attributed to the floodwater retarding structures is estimated to be $2,308 annually.

It is estimated that the project will produce local secondary benefits averaging $17,080 annually. Secondary benefits from a National viewpoint were not considered pertinent to the economic evaluation.

Since the watershed is not located in an area designated by the Secretary of Agriculture under the Area Redevelopment Act, no redevelopment benefits were claimed.

The total flood prevention benefits from structural measures are estimated to be $198,497. In addition to the monetary benefits, there are other substantial benefits which will accrue to the project such as an increased sense of security, better living conditions, and improved wildlife conditions.

None of these additional benefits were evaluated in monetary terms nor have they been used for project justification.

COMPARISON OF BENEFITS AND COSTS

The average annual cost of structural measures (amortized total installation cost, plus operations and maintenance) is estimated to be $137,094. The structural measures are expected to produce average annual primary benefits of $181,417, or $1.32 for each dollar of cost.

The ratio of the total average annual project benefits ($198,497) to the average annual cost of structural measures ($137,094) is 1.45 to 1 (table 6).

PROJECT INSTALLATION

Land Treatment Measures

Land treatment measures, itemized in table 1, will be established by farmers and ranchers during an 8-year period in cooperation with the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts. Technical assistance in the planning and application of land treatment measures is provided under the going program of the districts. A standard soil survey is in progress and has been completed on 198,286 acres. There are 37,234 acres needing standard soil survey.

The governing bodies of the soil conservation districts will assume aggressive leadership in getting the planned land treatment measures installed. The landowners and operators within the watershed will be encouraged to apply and maintain soil and water conservation measures on their farms and ranches. District owned equipment will be made available to the landowners in accordance with existing arrangements for equipment usage in each district. The Soil Conservation Service will provide technical assistance to the soil conservation districts to assist landowners and operators cooperating with the districts in accelerating the planning and application of soil, plant, and water conservation measures, including treatment for areas of severe gullying. Additional technical assistance will be provided to the Hamilton-Coryell Soil Conservation District to accelerate the completion of needed standard soil survey.

The soil and water conservation loan program of the Farmers Home Administration is available to all eligible farmers and ranchers in the area. Educational meetings will be held in cooperation with other agencies to outline the services available and eligibility requirements. Present Farmers Home Administration clients will be encouraged to cooperate in the program.

The County Agricultural Stabilization and Conservation committees will cooperate with the governing bodies of the soil conservation districts by

selecting and providing financial assistance for those practices which will accomplish the conservation objectives in the shortest possible time.

The Extension Service will assist with the educational phase of the program by conducting general information and local farm meetings; preparing radio, television, and press releases; and using other methods of getting information to landowners and operators in the watershed.

Structural Measures

The Commissioners Courts of Erath and Hamilton Counties, Texas have the right of eminent domain under applicable State law and have financial resources to fulfill their responsibilities.

The Commissioners Court of Erath County will:

1. Obtain the necessary land, easements, and rights-of-way and permits for floodwater retarding structures 1 through 19, and 23, 24, and 26 to be dedicated to the Erath County and the Bosque Soil Conservation District;

2. Obtain necessary land, easements, and rights-of-way and permits for floodwater retarding structures 20, 21, 22, 25, and 27 to be dedicated to Erath County and the Upper Leon Soil Conservation District;

3. Provide for the relocation or modification of utility lines and systems, roads, and privately owned improvements;

4. Provide the necessary legal, administrative and clerical personnel, facilities, supplies, and equipment to advertise, award, and administer contracts;

5. Determine the legal adequacy of the easements and permits for construction; and

6. Be the contracting agency, and let and service all contracts for construction in Erath County.

The Commissioners Court of Hamilton County will:

1. Obtain the necessary land, easements, and rights-of-way and permits for floodwater retarding structure 28 to be dedicated to Hamilton County and the Hamilton-Coryell Soil Conservation District;

2. Provide for the necessary legal, administrative and clerical personnel, facilities, supplies, and equipment to advertise, award, and administer the contract;

3. Determine the legal adequacy of the easements and permits for construction; and

4. Be the contracting agency, and let and service the contract for construction in Hamilton County.

The Commissioners Courts of Erath, Hamilton and Bosque counties will provide the necessary improvement of low water crossings on public roads, within the boundaries of said watershed within the respective counties, to make them passable during prolonged release flows from the structures or give permission to inundate such road crossings where alternate routes are designated for use during periods of inundation.

Technical assistance will be provided by the Soil Conservation Service in preparation of plans and specifications, supervision of construction, preparation of contract payment estimates, final inspection, execution of certificates of completion, and related tasks necessary to install the planned structural measures for flood prevention.

The 28 floodwater retarding structures are scheduled to be constructed in numerical sequence during a 5-year installation period. Where structures are in series the uppermost structures will be constructed prior to, or concurrently with the lower structures.

FINANCING PROJECT INSTALLATION

Federal assistance for carrying out works of improvement described in this work plan will be provided under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83 Congress; 68 Stat. 666), as amended.

Funds for the local share of the project costs, including land, easements, rights-of-way, and administration of contracts, are available in the general funds of the counties and are supported by revenue from existing taxes.

It is anticipated that approximately 90 percent of the easements will be donated. The out-of-pocket cost of easements which will not be donated, relocation of utilities, roads and improvements, legal services, and administration of contracts is estimated by the sponsors to be $60,000.

The sponsoring local organizations do not plan to use loan provisions of the Act.

The structural measures will be constructed during a 5-year installation period pursuant to the following conditions:

1. The requirements for land treatment in the drainage area above the floodwater retarding structures have been satisfied.

2. All land, easements, rights-of-way, and permits have been obtained for all structural measures or a written statement is furnished by the Commissioners Courts of Erath and Hamilton Counties that their rights of eminent domain will be used, if needed, to secure any remaining land, easements, or rights-of-way within the project installation period; and that sufficient funds are available for purchasing those easements and rights-of-way.

3. Court orders have been obtained from the Erath County Commissioners Court showing that:

   a. County roads affected by the detention pools of floodwater retarding structures 3, 6, 9, 12, and 25 will either be raised two feet above emergency spillway crest elevation at no expense to the Federal Government, closed, or permission granted to temporarily inundate the road provided alternate routes are available.

   b. The county roads affected by the embankment and pool areas of floodwater retarding structures 6, 16, and 18 will either be closed or relocated at no expense to the Federal Government.

4. Provisions have been made for improving low water crossings or bridges and/or culverts on public roads or court orders or necessary permits obtained granting permission to temporarily inundate the crossings, providing alternate routes are available for use by all people concerned, during periods when these crossings are impassable due to prolonged flow from the principal spillways of the floodwater retarding structures. If alternate routes are not available, the provisions will specify that necessary improvements will be made, at no cost to the Federal Government, to make the crossings passable during prolonged periods of release flows from the structures.

5. Utilities, such as power lines, telephone lines, and pipelines, have been relocated or permission has been obtained to inundate the properties involved.

6. The contracting agency is prepared to discharge its responsibilities.

7. The project agreements have been executed.

8. Operation and maintenance agreements have been executed.

9. Public Law 566 funds are available.

The various features of cooperation between the cooperating parties have been covered in appropriate memorandums of understanding and working agreements.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by landowners and operators of the farms and ranches on which the measures are applied under agreement with the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts. Representatives of the soil conservation districts will make periodic inspections of the land treatment measures to determine maintenance needs and encourage landowners and operators to perform maintenance. They will make district-owned equipment available for this purpose in accordance with existing working arrangements.

Structural Measures

The Commissioners Court of Erath County and the North Bosque Water Control and Improvement District will be responsible for the operation and maintenance of the 27 floodwater retarding structures (1 through 27) in Erath County. The Commissioners Court of Hamilton County and the North Bosque Water Control and Improvement District will be responsible for operation and maintenance of the floodwater retarding structure (28) in Hamilton County. Funds for this purpose will come from the general fund of the county in which the structures are located. The general fund of each county is supported by existing taxes and is available and adequate for this purpose.

The estimated average annual cost of operation and maintenance of the 28 floodwater retarding structures is $5,344, of which $5,154 is for structures in Erath County and $190 is for the structure in Hamilton County.

The 28 floodwater retarding structures will be inspected at least annually and after each heavy rain by representatives of the North Bosque Water Control and Improvement District and representatives of the appropriate County Commissioners Court and Soil Conservation District. A Soil Conservation Service representative will participate in these inspections at least annually. For the floodwater retarding structures items of inspection will include, but will not be limited to, the condition of the principal spillway and its appurtenances, the vegetative cover of the earth fill and the emergency spillway, and fences and gates installed as a part of the structure. The items of inspection are those most likely to require maintenance.

The Soil Conservation Service, through the Bosque, Hamilton-Coryell, and the Upper Leon Soil Conservation Districts, will participate in operation and maintenance only to the extent of furnishing technical assistance to

aid in inspections and furnishing technical guidance and information necessary for the operation and maintenance program.

Provisions will be made for free access of representatives of the sponsoring local organizations and Federal agencies to inspect and provide maintenance for structural measures and their appurtenances at any time.

The sponsoring local organizations will maintain a record of all maintenance inspections made and maintenance performed and have it available for inspection by Soil Conservation Service personnel.

The sponsoring local organizations fully understand their obligations for maintenance and will execute specific maintenance agreements prior to the issuance of invitations to bid on the construction of the structural measures.

The necessary maintenance work will be accomplished either by contract, force account, or equipment owned by the respective County Commissioners Courts.

TABLE 1 - ESTIMATED PROJECT INSTALLATION COST

Upper Bosque River Watershed, Texas

Installation Cost Items	Unit	Number to be Applied Non-Federal Land 2/	Estimated Cost (Dollars) 1/ Public Law 566 Funds	Other Funds	Total
LAND TREATMENT					
Soil Conservation Service					
Conservation Cropping System	Acre	43,107	-	0	0
Contour Farming	Acre	23,705	-	85,969	85,969
Cover and Green Manure Crops	Acre	19,967	-	1,676,016	1,676,016
Crop Residue Use	Acre	43,107	-	552,942	552,942
Pasture Planting	Acre	5,360	-	134,000	134,000
Pasture Proper Use	Acre	9,632	-	50,687	50,687
Range Deferred Grazing	Acre	32,479	-	195,222	195,222
Range Proper Use	Acre	95,252	-	657,709	657,709
Range Seeding	Acre	2,819	-	33,828	33,828
Brush Control (Range)	Acre	12,674	-	126,740	126,740
Diversions	Feet	193,689	-	19,369	19,369
Grassed Waterway	Acre	355	-	24,850	24,850
Farm Ponds	No.	121	-	60,500	60,500
Terraces, Gradient	Feet	471,031	-	23,552	23,552
Technical Assistance			81,420	93,600	175,020
SCS Subtotal			81,420	3,734,984	3,816,404
TOTAL LAND TREATMENT			81,420	3,734,984	3,816,404
STRUCTURAL MEASURES					
Soil Conservation Service					
Floodwater Retarding Structures	No.	28	3,285,400	-	3,285,400
SCS Subtotal			3,285,400	-	3,285,400
Subtotal - Construction			3,285,400	-	3,285,400
Installation Services					
Soil Conservation Service					
Engineering Services			424,892	-	424,892
Other			282,724	-	282,724
SCS Subtotal			707,616	-	707,616
Subtotal - Installation Services			707,616	-	707,616
Other Costs					
Land, Easements, and Rights-of-Way			-	306,996	306,996
Administration of Contracts			-	14,000	14,000
Subtotal - Other			-	320,996	320,996
TOTAL STRUCTURAL MEASURES			3,993,016	320,996	4,314,012
TOTAL PROJECT			4,074,436	4,055,980	8,130,416
SUMMARY					
Subtotal SCS			4,074,436	4,055,980	8,130,416
TOTAL PROJECT			4,074,436	4,055,980	8,130,416

1/ Price Base: 1962

2/ It is expected that this level of application of the management and recurring type practices will be reached by the end of the project period.

TABLE 2 - ESTIMATED STRUCTURE COST DISTRIBUTION

Upper Bosque River Watershed, Texas
(Dollars) 1/

Structure Site Number	Installation Cost - Public Law 566 Funds				Installation Cost - Other Funds			Total Installation Cost
		Installation Services						
	Construction	Engineering	Other	Total Public Law 566	Adm. of Contracts	Easements and R/W	Total Other	
Floodwater Retarding Structures								
1	115,049	14,956	9,906	139,911	500	12,213	12,713	152,624
2	90,483	13,572	7,929	111,984	500	21,126	21,626	133,610
3	123,415	16,044	10,627	150,086	500	15,645	16,145	166,231
4	98,993	14,849	8,675	122,517	500	6,266	6,766	129,283
5	77,888	11,683	6,825	96,396	500	5,784	6,284	102,680
6	119,620	15,551	10,300	145,471	500	20,361	20,861	166,332
7	82,900	12,435	7,264	102,599	500	13,940	14,440	117,039
8	79,334	11,900	6,952	98,186	500	9,678	10,178	108,364
9	123,255	16,023	10,613	149,891	500	25,391	25,891	175,782
10	107,517	13,977	9,258	130,752	500	13,933	14,433	145,185
11	119,025	15,473	10,249	144,747	500	19,142	19,642	164,389
12	121,914	15,849	10,498	148,261	500	15,025	15,525	163,786
13	93,561	14,034	8,199	115,794	500	9,989	10,489	126,283
14	70,524	10,579	6,180	87,283	500	12,919	13,419	100,702
15	122,687	15,949	10,564	149,200	500	18,619	19,119	168,319
16	107,598	13,988	9,265	130,851	500	13,494	13,994	144,845
17	293,610	29,361	24,610	347,581	500	11,575	12,075	359,656
18	131,582	17,106	11,330	160,018	500	8,150	8,650	168,668
19	94,014	14,102	8,238	116,354	500	6,125	6,625	122,979
20	99,275	12,906	8,548	120,729	500	3,000	3,500	124,229
21	139,062	18,078	11,974	169,114	500	4,650	5,150	174,264
22	57,159	10,289	5,140	72,588	500	2,425	2,925	75,513
23	65,207	9,781	5,714	80,702	500	1,725	2,225	82,927
24	121,531	15,799	10,464	147,794	500	6,725	7,225	155,019
25	166,035	18,264	14,044	198,343	500	10,721	11,221	209,564
26	62,383	9,357	5,467	77,207	500	1,975	2,475	79,682
27	308,138	30,814	25,828	364,780	500	11,750	12,250	377,030
28	93,641	12,173	8,063	113,877	500	4,650	5,150	119,027
GRAND TOTAL	3,285,400	424,892	282,724	3,993,016	14,000	306,996	320,996	4,314,012

1/ Price Base: 1962

February 1963

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES
Upper Bosque River Watershed, Texas

Item	Unit	STRUCTURE NUMBER 1	2	3	4	5	6	7	8	9	10
Drainage Area	Sq.Mi.	4.57	5.15 1/	5.99	2.45	1.95	4.08	1.33	3.52	9.97 1/	5.33
Storage Capacity											
Sediment Pool (50-year or 200 acre-feet limit)	Ac.Ft.	137	200	198	115	76	172	45	96	200	200
Sediment Reserve (Below Riser)	Ac.Ft.	133	286	361	112	74	170	45	94	645	255
Sediment in Detention Pool	Ac.Ft.	54	96	112	45	29	67	18	38	165	91
Floodwater Detention	Ac.Ft.	1,636	1,843	2,179	908	631	1,658	555	1,259	3,568	1,976
Total	Ac.Ft.	1,960	2,425	2,850	1,180	810	2,067	663	1,487	4,578	2,522
Surface Area											
Sediment Pool (50-year or 200 acre-feet limit)	Acre	28	47	40	23	23	46	20	23	48	49
Sediment Reserve Pool (Top of Riser)	Acre	45	84	85	35	34	64	27	34	143	87
Floodwater Detention Pool	Acre	203	265	255	104	97	215	84	137	398	255
Volume of Fill	Cu.Yd.	184,480	151,890	238,900	174,660	100,000	210,950	137,180	145,020	210,620	192,080
Elevation Top of Dam	Foot	1438.2	1386.0	1381.2	1356.4	1359.2	1335.1	1303.5	1468.1	1417.2	1412.1
Maximum Height of Dam	Foot	40	30	37	33	29	31	26	32	35	30
Emergency Spillway											
Crest Elevation	Foot	1435.2	1382.5	1377.7	1353.2	1354.7	1329.2	1298.1	1464.1	1413.3	1408.7
Bottom Width	Foot	130	100	100	100	150	250	100	50	120	80
Type		Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.
Percent Chance of Use 4/		1.3	1.3	1.3	1.5	2.0	1.0	1.0	1.4	1.2	1.4
Average Curve No. - Condition II		78	78	79	80	79	78	78	78	78	80
Emergency Spillway Hydrograph											
Storm Rainfall (6-hour) 5/	Inch	6.29	6.70	6.73	6.45	9.77	13.00	13.00	6.36	5.98	6.23
Storm Runoff	Inch	3.85	4.22	4.34	4.19	7.18	10.15	10.15	3.91	3.58	3.99
Velocity of Flow (V_c) 6/	Ft./Sec.	0.0	0.0	0.0	0.0	3.5	5.0	4.8	0.0	0.0	0.0
Discharge Rate 6/	C.F.S.	0	0	0	0	210	1,170	347	0	0	0
Maximum Water Surface Elevation 6/	Foot	-	-	-	-	1355.7	1331.0	1299.7	-	-	-
Freeboard Hydrograph											
Storm Rainfall (6-hour) 7/	Inch	14.85	14.16	14.60	15.21	21.87	30.60	30.60	15.02	13.79	14.70
Storm Runoff	Inch	11.94	11.27	11.83	12.58	18.97	27.46	27.46	12.11	10.91	12.08
Velocity of Flow (V_c) 6/	Ft./Sec.	7.3	7.9	8.1	7.6	9.1	10.5	10.0	8.6	8.5	7.8
Discharge Rate 6/	C.F.S.	1,600	1,550	1,640	1,325	3,580	9,160	3,210	965	2,295	1,227
Maximum Water Surface Elevation 6/	Foot	1438.2	1386.0	1381.2	1356.4	1359.2	1335.1	1303.5	1468.1	1417.2	1412.1
Principal Spillway											
Capacity - Low Stage	C.F.S.	46	97	60	25	20	41	13	35	135	53
Capacity Equivalents											
Sediment Volume	Inch	1.33	2.12	2.10	2.08	1.72	1.88	1.52	1.21	1.90	1.92
Detention Volume	Inch	6.71	6.71	6.82	6.95	6.07	7.62	7.82	6.71	6.71	6.95
Spillway Storage	Inch	2.84	3.89	3.67	2.77	4.77	7.00	7.54	3.40	3.02	3.55
Class of Structure		A	A	A	A	B	C	C	A	A	A

(See Footnotes on last page of table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued
Upper Bosque River Watershed, Texas

Item	Unit	STRUCTURE NUMBER 11	12	13	14	15	16	17	18	19	20
Drainage Area	Sq.Mi.	5.57	3.90	4.49	1.47	4.33	6.65	20.62	7.49	8.65	2.95
Storage Capacity											
Sediment Pool (50-year or 200 acre-feet limit)	Ac.Ft.	178	181	158	74	185	199	198	200	198	110
Sediment Reserve (Below Riser)	Ac.Ft.	173	179	156	73	182	330	1,298	204	309	107
Sediment in Detention Pool	Ac.Ft.	68	71	62	29	69	106	286	51	70	28
Floodwater Detention	Ac.Ft.	1,993	1,242	1,633	535	1,420	1,472	4,751	1,702	1,951	511
Total	Ac.Ft.	2,412	1,673	2,009	711	1,856	2,107	6,533	2,157	2,528	756
Surface Area											
Sediment Pool (50-year or 200 acre-feet limit)	Acre	48	36	38	18	49	40	45	31	32	18
Sediment Reserve Pool (Top of Riser)	Acre	68	60	58	29	70	71	147	46	55	28
Floodwater Detention Pool	Acre	219	165	183	77	195	176	370	148	163	72
Volume of Fill	Cu.Yd.	201,580	194,480	162,490	107,610	163,680	195,300	440,890	179,700	178,660	115,610
Elevation Top of Dam	Foot	1389.8	1363.4	1355.5	1345.0	1287.2	1257.6	1207.0	1208.2	1193.3	1193.0
Maximum Height of Dam	Foot	34	32	32	30	31	42	53	42	49	33
Emergency Spillway											
Crest Elevation	Foot	1386.3	1358.4	1351.9	1340.7	1282.7	1252.5	1200.5	1203.5	1188.3	1188.5
Bottom Width	Foot	100	200	100	120	300	200	350	600 2/	300	220
Type		Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Rock	Rock	Veg.	Rock
Percent Chance of Use 4/		1.2	2.0	1.4	1.5	2.0	4.0	4.0	4.0	4.0	7.4
Average Curve No. - Condition II		78	79	79	79	80	79	81	80	80	81
Emergency Spillway Hydrograph											
Storm Rainfall (6-hour) 5/	Inch	6.22	9.49	6.26	9.86	9.45	6.15	5.66	6.10	6.04	6.41
Storm Runoff	Inch	3.78	6.91	3.92	7.26	7.00	3.82	3.58	3.87	3.82	4.26
Velocity of Flow (V_c) 6/	Ft./Sec.	0.0	4.0	0.0	1.0	3.5	0.0	0.0	0.0	0.0	4.0
Discharge Rate 6/	C.F.S.	0	411	0	60	407	0	0	0	D	500
Maximum Water Surface Elevation 6/	Foot	-	1359.5	-	1341.4	1283.6	-	-	-	-	1189.8
Freeboard Hydrograph											
Storm Rainfall (6-hour) 7/	Inch	14.69	21.26	14.77	22.09	21.17	14.52	13.35	14.39	14.26	15.12
Storm Runoff	Inch	11.79	18.35	12.00	19.40	18.39	11.75	10.88	11.78	11.64	12.62
Velocity of Flow (V_c) 6/	Ft./Sec.	8.0	9.6	8.0	8.8	9.0	9.6	10.8	8.0	9.6	9.1
Discharge Rate 6/	C.F.S.	1,574	5,671	1,575	2,575	6,857	5,700	14,069	9,425	8,343	5,200
Maximum Water Surface Elevation 6/	Foot	1389.8	1363.4	1355.5	1345.0	1287.2	1257.6	1207.0	1208.2	1193.3	1193.0
Principal Spillway											
Capacity - Low Stage	C.F.S.	56	39	45	15	43	67	206	75	87	30
Capacity Equivalents											
Sediment Volume	Inch	1.41	2.07	1.57	2.25	1.89	1.79	1.62	1.14	1.25	1.56
Detention Volume	Inch	6.71	5.97	6.82	6.82	6.15	4.15	4.32	4.26	4.23	3.25
Spillway Storage	Inch	2.83	4.85	2.32	4.98	4.64	2.76	2.47	2.00	1.95	2.34
Class of Structure		A	B	A	B	B	A	A	A	A	A

(See Footnotes on last page of table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued
Upper Bosque River Watershed, Texas

Item	Unit	STRUCTURE NUMBER 21	22	23	24	25	26	27	28	Total
Drainage Area	Sq.Mi.	4.51	2.33	1.86	8.81	6.66	1.79	20.72	5.64	162.78
Storage Capacity										
Sediment Pool (50-year or 200 acre-feet limit)	Ac.Ft.	200	78	61	197	156	60	199	117	4,188
Sediment Reserve (Below Riser)	Ac.Ft.	197	76	61	301	157	59	1,028	118	7,183
Sediment in Detention Pool	Ac.Ft.	53	19	15	66	39	15	155	42	1,959
Floodwater Detention	Ac.Ft.	1,068	571	427	1,978	1,481	412	4,983	1,257	45,600
Total	Ac.Ft.	1,518	744	564	2,542	1,833	546	6,365	1,534	58,930
Surface Area										
Sediment Pool (50-year or 200 acre-feet limit)	Acre	33	13	10	32	30	10	26	18	874
Sediment Reserve Pool (Top of Riser)	Acre	51	24	15	67	37	15	125	38	1,642
Floodwater Detention Pool	Acre	111	60	41	170	112	36	300	124	4,735
Volume of Fill	Cu.Yd.	184,900	119,440	115,268	195,700	320,680	114,360	472,248	174,940	5,383,316
Elevation Top of Dam	Foot	1194.5	1146.7	1172.5	1125.2	1081.1	1101.2	1151.3	1203.7	xxx
Maximum Height of Dam	Foot	39	35	44	45	46	43	67	42	xxx
Emergency Spillway										
Crest Elevation	Foot	1190.3	1142.1	1167.6	1119.6	1076.3	1096.2	1141.6	1198.4	xxx
Bottom Width	Foot	250	110	100	250	300	100	800 3/	200	xxx
Type		Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	xxx
Percent Chance of Use 4/		4.0	3.4	4.0	4.0	4.0	4.0	3.2	4.0	xxx
Average Curve No. - Condition II		81	78	79	80	79	79	79	79	xxx
Emergency Spillway Hydrograph										
Storm Rainfall (6-hour) 5/	Inch	6.33	6.51	6.70	6.03	6.22	6.52	12.30	4.53	xxx
Storm Runoff	Inch	4.19	4.04	4.31	3.81	3.88	4.15	9.60	2.40	xxx
Velocity of Flow (V_c) 6/	Ft./Sec.	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	xxx
Discharge Rate 6/	C.F.S.	0	0	0	0	0	0	19,793	0	xxx
Maximum Water Surface Elevation 6/	Foot	-	-	-	-	-	-	1146.2	-	xxx
Freeboard Hydrograph										
Storm Rainfall (6-hour) 7/	Inch	15.07	15.38	15.94	14.24	14.67	15.40	28.95	15.01	xxx
Storm Runoff	Inch	12.57	12.45	13.14	11.63	11.90	12.91	25.99	12.23	xxx
Velocity of Flow (V_c) 6/	Ft./Sec.	8.9	9.2	9.5	10.2	9.2	9.5	13.6	9.9	xxx
Discharge Rate 6/	C.F.S.	5,500	2,725	2,690	8,592	7,528	2,722	62,600	6,124	xxx
Maximum Water Surface Elevation 6/	Foot	1194.5	1146.7	1172.5	1125.2	1081.1	1101.2	1151.3	1203.7	xxx
Principal Spillway										
Capacity - Low Stage	C.F.S.	45	23	19	88	100	18	207	56	xxx
Capacity Equivalents										
Sediment Volume	Inch	1.87	1.39	1.38	1.20	0.99	1.40	1.25	0.92	xxx
Detention Volume	Inch	4.44	4.60	4.31	4.21	4.17	4.32	4.51	4.18	xxx
Spillway Storage	Inch	2.13	2.53	2.36	2.34	1.74	2.10	3.14	2.72	xxx
Class of Structure		A	A	A	A	A	A	C	A	xxx

1/ Exclusive of area controlled by other structures. The entire area considered in emergency spillway design.
2/ Two emergency spillways on right end of dam (380' and 220').
3/ 400' emergency spillway on each end of dam.
4/ Based on regional analysis of gaged runoff and in all cases exceeds the requirements set forth in Engineering Memorandum SCS-27.
5/ Minimum 6-hour precipitation for emergency spillway hydrograph for Class C structures. 0.5 P reduced to controlling drainage area on all Class A structures. 0.75 P reduced to controlling drainage area on all Class B structures.
6/ Maximum during passage of hydrograph.
7/ Probable maximum 6-hour precipitation from U. S. Department of Commerce, Weather Bureau, TP Number 40, for Class C structures. 1.18 P reduced to controlling drainage area on all Class A structures except 1.19 P on Site Numbers 21, 23, and 28. 1.68 P reduced to controlling drainage area on all Class B structures.

TABLE 4 - ANNUAL COST

Upper Bosque River Watershed, Texas
(Dollars)

Evaluation Unit	Amortization of Installation Cost 1/	Operation and Maintenance Cost 2/	Total
Floodwater Retarding Structures			
1 through 28 3/	131,750	5,344	137,094
TOTAL	131,750	5,344	137,094

1/ Price Base: 1962 prices amortized for 100 years at 2.875 percent.

2/ Long-term prices as projected by ARS, September 1957.

3/ Interrelated measures.

February 1963

TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Upper Bosque River Watershed, Texas
(Dollars)

Evaluation Unit	AVERAGE ANNUAL BENEFITS 1/ Flood Prevention: Damage Reduction	Recreation 2/	Other 3/	Secondary	Total	Average Annual Cost 4/	Benefit Cost Ratio
Floodwater Retarding Structures							
1 through 28 5/	161,235	8,830	11,352	17,080	198,497	137,094	1.4:1
GRAND TOTAL	161,235 6/	8,830	11,352	17,080	198,497	137,094	1.4:1

1/ Price Base: Long-term prices as projected by ARS, September 1957.
2/ Benefits from recreation incidental to installation of floodwater retarding structures.
3/ Includes $9,044 from reduction in damages to Bosque River flood plain from bottom of watershed to Waco Reservoir and $2,308 from reduction in sediment deposition to Waco Reservoir.
4/ From Table 4.
5/ Interrelated measures.
6/ In addition, it is estimated that land treatment measures will provide flood damage reduction benefits of $6,462.

February 1963

INVESTIGATIONS AND ANALYSES

Project Formulation

Land Treatment Measures

The status of land treatment measures for the watershed was developed by the Bosque, Hamilton-Coryell, and Upper Leon Soil Conservation Districts assisted by personnel from the Soil Conservation Service at Dublin, Stephenville, Hamilton, and Meridian. Conservation needs data were compiled from existing conservation plans within the watershed and expanded to represent the conservation needs of the entire watershed. The quantity of each land treatment practice which contributes directly to watershed protection and flood prevention that will be applied during the 8-year installation period was estimated (table 1). The hydraulic, hydrologic, sedimentation, and economic investigations provided data as to the effects of these measures in terms of the reduction of flood damage. Although measurable benefits would result from application of these needed land treatment measures, it was apparent that other flood prevention measures would be required to attain the degree of watershed protection and flood damage reduction desired by the local people.

Structural Measures

Structural measures for flood prevention needed to attain the project objective were then determined. The study made and the procedures used in that determination were as follows:

1. A base map of the watershed was prepared to show watershed boundary, drainage pattern, system of roads and railroads, and other pertinent information.

2. A study of aerial photographs supplemented by field examination indicated the limits of flood plain subject to flood damage.

3. All probable sites for floodwater retarding structures were located by study of U. S. Geological Survey topographic maps, stereoscopic photo study, and field examination. Sites for which it was apparent that sufficient storage capacities could not be developed were dropped from further consideration. A watershed map was used to show locations of all structure sites that could possibly be used in alternate systems to meet the project objectives. This map was submitted to the sponsoring local organizations who provided data on ownership of land apparently involved in each site location. The sponsoring local organizations also provided

estimates on values of easements involved in each site. Based on apparent physical, economic, and easement feasibility, the Service and sponsoring local organizations agreed that 37 possible sites for floodwater retarding structures would be investigated. Out of the 37 sites investigated, a system of 28 sites was determined to be feasible.

4. A topographic map was made of the pool, dam, and emergency spillway areas of the probable sites. These surveys provided necessary information to determine if the required sediment and floodwater detention storage could be obtained, the limit of the pool areas, estimated installation costs, and the most economical design for each structure. The sediment and floodwater storage requirements, structure classification, and principal and emergency spillway layout and design meet or exceed criteria outlined in Engineering Memorandum SCS-27 and Texas State Manual Supplement 2441.

   To meet the minimum requirements for level of protection for urban areas, as set forth in the Watershed Protection Handbook, the works of improvement should provide protection against major damages resulting from a recurrence of the largest storm of record or from one of 100-year frequency, whichever is greater. The volume of runoff flood routed as the design storm for evaluation was the runoff from the maximum 24-hour rainfall, 100-year frequency storm, 6.81 inches. For those sites above Stephenville this amount was used to determine detention storage for structures, insofar as topography and feasibility permitted. At 12 of the 14 sites this was accomplished. At the other 2 sites regional analysis of gaged runoff was used to determine detention storage by classification. Because the detention storage of these 2 sites was less than the runoff from the design storm, the routed 100-year frequency outflow through the emergency spillways of these 2 structures was flood routed to obtain a modified peak for the 100-year storm used in evaluation.

   At 12 of the 14 sites below Stephenville regional analysis of gaged runoff was used to determine detention storage, by classification. The maximum detention storage that was possible at Site 20 was the 6-hour 25-year frequency runoff and at Site 27 was the 6-hour 100-year frequency runoff as set forth in Engineering Memorandum SCS-27.

   Above Hico there are 23 structures (including 10 in Green Creek watershed) that do not have the detention storage of the 100-year frequency flood routed for evaluation. These structures, controlling a total of 133.07 square

miles, will discharge through the emergency spillways when the 50-year and 100-year floods are routed through them. The total peak discharge from these structures was calculated for the 50-year and 100-year frequency events. Concordant flow procedure was applied to these discharges and added to the discharge from the uncontrolled areas and the release rates from the structures to determine the peak discharge for these two flood frequencies at Hico under project conditions.

To determine the most economical design of the floodwater retarding structures, consideration was given to the quantity of rock excavation in the emergency spillways. Multiple routings of freeboard hydrographs were made for all sites and series of sites to determine the spillway proportion and height of dam which would result in the most economical and feasible design of the structures.

Plans of a floodwater retarding structure, typical of those planned for the watershed, are illustrated by plates 5 and 5A.

5. A detailed investigation was made of State, County, and farm roads having low water crossings on streams below the floodwater retarding structures. Where there were no equal alternate routes, the improvements required to provide passage during periods of prolonged floodwater release from the structures were determined.

6. The local sponsoring organizations or other interests did not desire to incorporate additional water storage for any agricultural or nonagricultural purpose.

7. Structure data tables were developed to show for each structure, the drainage area, the capacity needed for floodwater detention and for sediment storage in acre-feet and in inches of runoff from the drainage area, the release rate of the principal spillway, acres inundated by the sediment, sediment reserve, and detention pools, the volume of fill in the dam, the estimated costs of the structure, and other pertinent data (tables 2 and 3).

8. Damages resulting from floodwater, sediment, and flood plain erosion were determined from damage schedules, surveys of sample areas, and flood routings under non-project conditions. Reductions in these damages resulting from the proposed works of improvement were estimated on the basis of reduction in sediment yields and reduction of peak discharges as determined by flood routings under future conditions for which it was assumed that the proposed works of improvement had been

installed. Benefits so determined were allocated to individual measures or groups of interrelated measures, on the basis of the effects of each on reduction of damages. In this manner, it was determined that floodwater retarding structures could be economically justified. By further analysis those individual and interrelated floodwater retarding structures which had favorable benefit to cost ratios were determined. Alternate sites were investigated until the most economical and feasible system of floodwater retarding structures was developed which would provide the degree of protection desired by the sponsoring local organizations.

This system consisted of 28 interrelated floodwater retarding structures necessary to provide the desired level of flood damage reduction.

When the structural measures for flood prevention had been determined, a table was developed to show the cost of the measures (table 2). The summation of the total costs for all works of improvement represented the estimated cost of the planned watershed protection and flood prevention project (table 1).

A second cost table was developed to show separately the annual installation cost, annual maintenance cost, and the total annual cost of the structural measures (table 4).

Hydraulic and Hydrologic Investigations

The following steps were taken as a part of the hydrologic investigations and determinations:

1. Basic meteorological and hydrologic data were tabulated from Climatological Bulletins, U. S. Weather Bureau, and Water Supply Papers, U. S. Geological Survey. These data were analyzed to determine average precipitation depth-duration relationships, the relationship of geology, soils, and climate to runoff depth for single storm events, and the runoff-peak discharge relationship.

2. In selecting the location of valley cross sections in the watershed, both agricultural and urban areas were considered. The needs of the economist and geologist were considered in making these selections. Urban valley cross sections were selected to determine the effects of various frequency storms at specific locations. These locations included areas of existing housing and business development, highways, streets, and parks.

3. Valley cross section rating curves were developed from field survey data collected in 2, above, by solving water surface profiles for various discharges. Computations of the water surface profiles were made by the use of the IBM 650 computer. Data thus developed included peak discharge-area inundated relationships at various elevations for each valley cross section considered. The theory of concordant flow was used to determine the relationship of peak discharge to volume of runoff.

4. Hydrologic conditions of the watershed were determined by considering such factors as climate, geology, topography, soils, land use, and vegetative cover. From this, soil-cover complex data were assembled and rainfall-runoff relationships were computed for use in determining the runoff from various frequency storms. These computations compared favorably with the best available gaged runoff data.

5. Stage-area inundation curves were developed from field survey data for each portion of the valley represented by a cross-section in agricultural reaches A, B, C, E, F, G, I, J, K, and L (plate 1). Area inundated, by incremental depths of inundation, was developed for these reaches by routing volumes of runoff from each storm in the evaluation series, using a peak discharge-volume relationship. Relationships between frequency-stage-damage were developed for the urban areas represented by evaluation Reaches D and H.

6. From a tabulation of cumulative departure from normal precipitation, the period 1941 through 1960, was determined to be representative of the normal precipitation on the watershed, and is the period from which the historical evaluation series was developed.

7. The maximum release rates for the principal spillways of the floodwater retarding structures were determined by a detailed study of the stream channel and the effect of release rates on the design of the structures. The maximum release rate for all structures will be 10 c.s.m. except Number 25 which will be 15 c.s.m.

8. The appropriate emergency spillway design storm was selected from the chart "Minimum Six-Hour Precipitation (inches) for Developing the Emergency Spillway Hydrograph for Class (c) Structures", U. S. Soil Conservation Service, December 1960. The appropriate freeboard spillway design storm was selected from Chart 50, U. S. Department of Commerce, Weather Bureau, Technical Paper No. 40.

9. The appropriate emergency spillway and freeboard design storms for Class A and Class B structures were selected from figures 3.21-1 and 3.21-4 of National Engineering Handbook, Section 4, Supplement A, in accordance with criteria contained in Engineering Memorandum SCS-27, and Texas State Manual Supplement 2441.

10. Emergency spillway capacities were designed in accordance with Texas State Manual Supplement 2441.

11. Breaching studies were made for structures where a breach might cause an undue hazard to life or property. Based on these studies, appropriate hazard classifications were determined and the structures were so designed.

Sedimentation Investigations

Sedimentation investigations were made in accordance with procedures as outlined in Watershed Memorandum EWP-7, "Sedimentation Investigations in Work Plan Development", August 21, 1959, Fort Worth, Texas and Technical Release No. 12, "Procedure for Computing Sediment Requirements for Retarding Reservoirs", September 1959.

Sediment Source Studies

Sediment source studies to determine the 100-year sediment storage requirements were made in the drainage areas of the 28 planned floodwater retarding structures. Detailed investigations were made in ten of these drainage areas. Estimates of sediment production rates, based on similarity to drainage areas which had been surveyed in detail, were made for the remaining 18 planned structures.

The 10 detailed investigations and computations included:

1. Mapping soils by units, percent slope, length of slope, land use, cover condition classes on rangeland, land treatment on cultivated land, and land capability classes.

2. Measuring lengths, widths, and depths, and estimating annual lateral erosion of all gullies and stream channels affected by erosion.

3. Measuring widths and depths and studying old aerial photographs to determine the average annual headward erosion of all headcuts and overfalls.

4. Computing annual gross erosion by sources (sheet, gully, and streambank).

Field studies and computations for the 18 planned structures not surveyed in detail included:

1. Mapping the land use.

2. Studying soils, topography, and erosion for comparison of similarity to drainage areas surveyed in detail.

3. Computing annual gross erosion based on erosion rates of detailed areas.

Estimates of annual gross erosion reflect the effect of expected land treatment on drainage areas of planned structures. A gradual improvement of watershed conditions is expected as a result of the installation of needed land treatment measures.

Sediment storage requirements for planned structures were determined by adjusting average annual total erosion for expected sediment delivery rates and for trap efficiency of reservoirs.

Flood Plain Sediment and Scour Damages

The following sediment and scour damage investigations were made to determine the nature and extent of physical damage to flood plain lands:

1. Field examinations were made within representative sample areas. Factors such as depth and texture of sediment deposits, texture and condition of soils underlying sediment deposits, depth, and width of scour channels, channel degradation or aggradation, and channel bank erosion were recorded. Areas of damage were mapped.

2. Estimates of past physical flood plain damage were obtained through interviews with landowners and operators.

3. A damage table was developed to show percent damage by texture and depth increment for sediment and by depth and width for scour. Due consideration was given to the agronomic practices, land treatment practices, soils, crop yields, and land capabilities in assigning damage categories.

4. The areas of sediment and scour damages were measured and tabulated by percent damage categories.

5. Damages measured within sample areas were expanded, by evaluation reaches, to represent the entire flood plain.

6. Estimates of recoverability of productive capacity were developed from field studies and interviews with farmers.

7. Average annual sediment yield from each source (sheet erosion, gully erosion, streambank erosion, and flood plain scour) was estimated from detailed sediment source studies and scour damage investigations. Sediment yields to each evaluation reach were computed for present conditions, with land treatment measures applied, and with the combined program of land treatment and structural measures installed. The reduction in sediment yield was adjusted to reflect the estimated importance of each sediment source as damage. The reduction of monetary damage from overbank deposition was based on the reduction in damaging sediment yield and reduction of area inundated by floodwater.

8. Estimates of the reduction of scour damage due to the installation of the project were based on reduction of depth and area inundated by floodwater.

Reservoir Sedimentation

The following procedure was used to estimate the average annual sediment yield from the Upper Bosque River watershed to Waco Reservoir for present conditions, with land treatment applied, and with the combined project of land treatment and structural measures installed.

1. Detailed sediment source investigations in drainage areas above 10 planned floodwater retarding structures and the study of flood plain scour and streambank erosion were used to estimate the average annual rates of erosion by sources (sheet, gully, streambank, and flood plain scour).

2. Rates of sediment delivery, by sources, were estimated, making allowance for such factors as size and shape of the watershed, channel density, channel gradient, channel capacity, texture of sediment, and stream channel length from the watershed to Waco Reservoir.

Geologic Investigations

Preliminary geologic investigations were made at each of the floodwater retarding structure sites to obtain information on the nature and extent of embankment and foundation materials, emergency spillway excavation, emergency spillway stability, and possible problems that might be encountered during construction. These investigations included surface observations of valley slopes, alluvium, channel banks, and exposed

geologic formations; seismic investigations; and hand auger borings. The findings of preliminary geologic investigations were used in making cost estimates of structures.

Description of Problems

Floodwater retarding structure sites can be placed into two groups for the purpose of discussing geologic conditions affecting construction. The groups are: (1) sites on the Paluxy formation outcrop and (2) sites on the Glen Rose formation outcrop.

(1) Sites on Paluxy Formation

Sites 1 through 15 are on the outcrop of the Paluxy formation.

Foundations - These sites are characterized by deep stratified alluvial clays, silts, and sands in the flood plain. The underlying Paluxy formation consists of sandy clays, poorly consolidated sandstones, siltstones, and thin seams of limestone. The permeable condition of the foundations may necessitate foundation drainage measures to prevent saturation of portions of embankments and downstream areas.

Emergency Spillways - Most emergency spillway excavation will be in sandy clays and poorly consolidated sandstones, but some rock excavation will be involved in the removal of limestone seams. The estimated percent of rock in emergency spillway excavation is:

Site No.	Percent Rock
2 through 4, 10, 11, 13 and 14	10
1, 6, 8, 9, and 15	15
12	20
5	25
7	70

The Paluxy formation is very susceptible to erosion. Emergency spillway cuts will be vegetated as soon as possible after construction.

Embankment Materials - An abundance of alluvial sandy clay, clayey sand, and silty clay is available within

sediment pool areas. Materials to be excavated from emergency spillways are suitable for use in the embankment. The higher embankments probably will need berms on the downstream slopes, as well as upstream, for erosion control purposes. Soils for embankments are mostly CL and SC with some occurrence of SP and SM, as classified in accordance with the Unified Soil Classification System.

(2) Sites on the Glen Rose Formation

Sites 16 through 28 are located on the outcrop of the Glen Rose formation.

Foundations - Although these sites are within an area of clay soils underlain by limestone and marl, the flood plain alluvium, derived mostly from the overlying Paluxy formation, is generally sandy. The Glen Rose formation has contributed gravelly deposits to flood plains as stream channels have been incised into limestone during their development. As a result, foundations are primarily stratified sandy clays, clayey sands, and silty sands with gravelly clay lenses underlain by interbedded hard limestones, marly limestones, and calcareous clays of the Glen Rose formation. The depth of cutoff trenches, if penetrating the alluvium and resting on the Glen Rose formation, will range from shallow to greater than 20 feet.

Emergency Spillways - Emergency spillway excavation will be in interbedded hard limestones, marly limestones, and clays. In general the overlying soils are less than 20 inches thick. Some thin bedded limestones can be removed by ripping, but blasting will be required for most emergency spillway excavation. The estimated percent of rock in emergency spillway excavation is:

Site No.	Percent Rock
18	40
16 and 19	50
17, 20 through 24, and 26	60
25,27 and 28	70

Some vegetation of emergency spillways will be necessary where soft marl and clay beds are exposed, but the alternating hard limestone beds will be very effective in maintaining stable spillways.

Embankment Materials - Sufficient volumes of embankment materials are available within sediment pools at all sites. The length of haul will not exceed 2,500 feet at any site. Materials to be excavated from emergency spillways are suitable for use in embankments. Rock raking to remove cobbles from gravelly lenses will be necessary. Berms on downstream slopes of higher embankments probably will be needed for erosion control purposes and slope stability. Soils for embankment are mostly CL, SC, and GC with some lenses of SM, SP, and GP, as classified in accordance with the Unified Soil Classification System.

Further Investigations

Detailed investigations, including exploration with core drilling equipment, will be made at all sites prior to construction. Laboratory tests will be made to determine the suitability of embankment and foundation materials and the methods of handling.

Economic Investigations

Selection of Evaluation Reaches

Because of the diversity of damageable values, frequency of flooding, and flood plain characteristics the flood plain was divided into 12 evaluation reaches (plate 1). Of these, one was in the urban area of Hico and one in Stephenville.

Determination of Agricultural Damages

The historical method of analysis was used to evaluate damages in the 10 evaluation reaches where damages are primarily agricultural in nature. Agricultural damage estimates were based on schedules obtained in the field covering about 51 percent of the agricultural flood plain. These schedules covered land use, crop distribution, yields, and historical data on flooding and flood damages.

In the calculation of crop and pasture damage, expenses saved, such as the cost of harvesting and other production inputs were deducted from the gross value of the damage. The flood plain land use was mapped in the field. Estimates of normal flood-free yields were based on data obtained from schedules, supplemented by other agricultural workers in the area. Information on other agricultural damages such as fences, livestock, and farm equipment was obtained from schedules and correlated with size of floods.

The monetary value of the physical damage to the flood plain from erosion and from deposition of sediment was based on the value of the production

lost, taking into account the time lag necessary for recovery.

Important items of indirect agricultural damage are the interruptions of travel or detours due to flooding which prevents marketing of milk and poultry products on schedule, losses sustained through inability to gain access to fields at optimum time for cultural operations, and additional expense for care of livestock. It was estimated that indirect damage would approximate 10 percent of the direct agricultural damage.

Determination of Nonagricultural Damage

The synthetic frequency method of analysis was used to evaluate damages in the urban areas of Hico and Stephenville. Information was collected in the field on damages experienced from the floods of 1952, 1955, 1956, and 1957. An evaluation was made in Hico of the damages that would occur from a flood which could be expected on an average of once in 100 years. Under without project conditions, a flood of this magnitude would result in a highwater elevation of about 1.1 foot higher than experienced in 1952. In Stephenville the flood of 1955 was a 100-year frequency event. High water marks from the experienced floods were used to determine peak stages which in turn were related to stages calculated for the synthetic series. Stage damage curves were developed to cover the range of damage producing floods. Average annual damages were calculated for each evaluation reach representing an urban area.

A careful study and analysis of the history of both Hico and Stephenville and the property values in the flood plain, both present and past, was made. From these studies, it was concluded that an increase in urban damageable values, through future development in the absence of a project, or benefits from urban enhancement are not predictable at this time. Therefore, no benefits of this type are included in the evaluation.

Estimates of damage to roads, bridges, and railroads were obtained from county commissioners, State highway officials, and railroad officials. These damage estimates were related to the size of floods.

Indirect damage associated with nonagricultural damage includes detours to travel, interruption of railroad service, temporary dislocation of residents from homes, and losses sustained by businesses during periods of rehabilitation. It is estimated that indirect damage would be about one-fifth of the direct nonagricultural damage.

Benefits from Reduction of Damage

Average annual damages within the watershed were calculated for conditions without a project, with land treatment installed, and after installation of the complete project. The difference between the damage after the installation of a phase of the project and that before its installation constituted the benefit from reduction of damage creditable to that phase.

At each phase considered, adjustments were made to take into account the effects of recurrent flooding when more than one flood occurred during the same year.

The monetary value of the reduction of sediment deposition in Waco Reservoir, creditable to the 28 floodwater retarding structures in this watershed, was calculated by use of the straight-line depreciation method of evaluation.

Installation of this project will result in significant damage reduction benefits downstream on the mainstem flood plain of the North Bosque River. Data prepared by the United States Study Commission-Texas provided information on the existing average annual flood damage in two evaluation reaches between the bottom of the watershed and Waco Reservoir. The 28 floodwater retarding structures proposed in this project will control an average of 28 percent of the drainage area contributing to the evaluation reach between this watershed and Clifton and 16 percent of the drainage area contributing to the evaluation reach between Clifton and Waco Reservoir. From plottings of percent control versus damage reduction creditable to floodwater retarding structures, an estimate was made of the reduction of damages that could be expected as a result of the structural measures in this watershed.

Restoration of Former Productivity Benefits

Farmers in the flood plain were asked to state changes made in land use as a result of past flooding. Operators were also asked what changes they would make in their use of flood plain lands if flooding were reduced. Analysis of their responses indicated that benefits from restoration of lands to their former use would result from the anticipated reduction in flooding. Factors considered in this analysis were the size and location of the areas affected, land capability, reduction in frequency and depth of flooding, and similar factors. Consideration was given to increased damage after restoration of production. All benefits are net benefits remaining after production, harvesting, and all other allied costs were considered. Benefits so claimed were discounted for an expected 5-year lag in conversion. It is expected that 874 acres will be restored with a resulting increase in net income of $10,068 annually. Consideration was given to the effects of acreage allotment restrictions and it was determined that such benefits are not dependent upon production increases in restricted crops. These benefits are included as crop and pasture benefits in table 5.

An example of the effects on restoration of production in a typical evaluation reach is shown in the following table:

Crop Distribution and Net Returns
Restoration of Former Productivity Benefits 1/
Evaluation Reach L

Crop Distribution	Without Project			With Project			Difference in Net Return
	Acres	Yield	Net Return (dollars)	Acres	Yield	Net Return (dollars)	
Grain Sorghum	89	22 cwt	1,411	114	22 cwt	1,807	396
Corn	28	38 bu.	605	48	38 bu.	1,036	431
Hay	170	2.25 ton	3,663	194	2.25 ton	4,180	517
Peanuts	119	28 bu.	4,584	119	28 bu.	4,584	-
Oats (Grain)	127	35 bu.	1,005	137	35 bu.	1,083	78
Oats (Grazing)	-	2.0 aum	678	-	2.0 aum	732	54
Temporary Pasture	235	6.0 aum	2,289	249	6.0 aum	2,513	224
Improved Pasture	29	5.0 aum	242	29	5.0 aum	242	-
Bermuda Pasture	137	2.5 aum	742	137	2.5 aum	742	-
Pasture (Formerly Cultivated)	70	1.5 aum	333	22	1.5 aum	104	- 229
Pasture	560	1.2 aum	2,128	560	1.2 aum	2,128	-
Idle	55	-	-	10	-	-	-
Miscellaneous	33	-	-	33	-	-	-
TOTAL	1,652		17,680	1,652		19,151	1,471

Difference in Net Returns	1,471
Less Discount for Lag in Conversion	86
Deduction for Associated Costs	43
Deduction for Added Flood Damage	44
Benefit from Restoration	1,298

1/ Long-term prices as projected by ARS, September 1957.

Incidental Recreation Benefits

Recreation benefits will occur incidental to the installation of the floodwater retarding structures proposed in this plan. Flood prevention was the only purpose considered in the location, capacity, and design of these structures and no additional project costs are involved in obtaining incidental recreation benefits from the storage in the sediment pools of the structures. When the structures are installed the sediment and sediment reserve pools will have a total surface area of 1,642 acres. In order to determine the minimum benefits, evaluation was limited to the pool areas that would result from the 50-year sediment storage or 200 acre-feet at each structure, whichever was less. Therefore, recreation benefits were estimated on the basis of a total surface area of 874 acres. Studies indicate that the pool areas considered will serve as desirable facilities for outdoor recreational activities. All of these pools are ideally located in relation to the population of the surrounding area. Present population within a 25 mile range of these structures is in excess of 35,000. Degree of utilization for recreation was estimated by comparing probable public access, total surface area, number and size of pools, population, and alternate facilities with Green Creek watershed, for which a comprehensive study of recreation utilization has been made. Green Creek watershed is adjacent to this watershed. This fact was considered in estimating the degree of utilization that can reasonably be expected to be made of the sediment pools of the structures in the Upper Bosque River watershed. It is estimated that the pool areas of the structures included in this project will attract an average of 13,600 visitors annually.

It is believed that most pool areas will ultimately have partially developed recreational facilities for fishing, swimming, hunting, boating, and picnicking, with many of the pool areas located near the urban centers having fully developed facilities. To assure a conservative estimate of benefits, a gross value of $1.00 per visitor day was used in the economic evaluation. Associated costs of development, including operation and maintenance costs, were deducted from the gross value of the benefits. A five-year period was considered for development and lag in utilization of these facilities. It was also considered that approximately the same level of utilization would prevail for about 50 years at which time sediment deposition would gradually reduce the attraction of the pools for recreational activities. Total annual net benefits, discounted to present worth, were estimated to average $8,830.

Secondary Benefits

Values of local secondary benefits were calculated in accordance with the interim procedures outlined in Watershed Memorandum SCS-57, October 3, 1962.

Secondary benefits of a local nature were considered as either (1) stemming from the project, or (2) induced by the project. Benefits

stemming from the project were considered to be at least 10 percent of the direct primary damage reduction benefits within the watershed. Secondary benefits resulting from primary recreational benefits and the additional production costs associated with restoration of former productivity were considered to be induced by the project. Secondary benefits were considered to be 10 percent of the average annual recreation benefits and 10 percent of the average annual increased production costs associated with restoration of former productivity.

The total annual net value of secondary benefits resulting from structural measures are estimated to be $17,080 of which $15,412 stem from the project and $1,668 are induced by the project.

Appraisal of Land and Easement Values

Areas that will be inundated by the sediment and detention pools of the floodwater retarding structures were excluded from the damage calculation. An estimate was made, however, of the value of the production that would be lost in those areas after installation of the project. In this appraisal it was considered that there would be no production in the sediment pools. The land covered by the detention pools was assumed to be converted to grassland under project conditions. The costs of land, easements, and rights-of-way for the 28 floodwater retarding structures were determined by individual appraisal in cooperation with representatives of the sponsoring local organizations. The floodwater retarding structure site costs were based on appraisals of the value of the easements with consideration given to the values that will remain after the land is devoted to project purposes.

The average annual net loss in production and associated secondary losses were calculated and this value compared with the amortized cost of the structure sites. The larger amount was used in the economic evaluation of the project to assure a conservative appraisal.

Details of Methodology

The evaluation of flood damages in the two evaluation reaches representing urban areas was made by flood routing a synthetic storm series. Evaluation of the ten evaluation reaches representing agricultural areas was made by flood routing a historical storm series for the period from 1941 through 1960. Details of the procedures used in these methods of evaluation are described in the Soil Conservation Service Economics Guide for Watershed Protection and Flood Prevention, December 1958.

Fish and Wildlife Investigations

The following is a summary of a reconnaissance study made by the Bureau of Sport Fisheries and Wildlife of the Fish and Wildlife Service, United States Department of the Interior, and concurred in by the Texas Game

and Fish Commission.

> "Our reconnaissance of the project indicates that fish and wildlife generally will be benefited by the watershed protection measures contemplated. The project will reduce the rate of sedimentation and improve the fishery in Waco Reservoir. Reduction of floods will benefit ground-nesting game birds in the bottom land.
>
> "Floodwater retarding structures with permanent pools would offer opportunities for fish and wildlife enhancement.
>
> It is recommended:
>
> 1. That wildlife food and cover plantings be made around flood retarding structures to improve wildlife habitat.
>
> 2. That clearing of vegetation be restricted to that required for construction of the dams and efficient operation of the structure.
>
> "Other than the above, there are no particular measures that should be incorporated into the project work plan to benefit fish and wildlife resources substantially, and no measures to prevent damages to these resources are required.
>
> No detailed studies by this Bureau are considered necessary."

Forest Investigations

The following is a summary of a reconnaissance study made by the United States Forest Service, Department of Agriculture, and concurred in by the Director of the Texas Forest Service.

> "Due to the character of the watershed no forestry measures are recommended or included in watershed work plan. However, if a need for forestry assistance develops, particularly in tree planting, the Texas Forest Service will furnish technical assistance to the landowners."

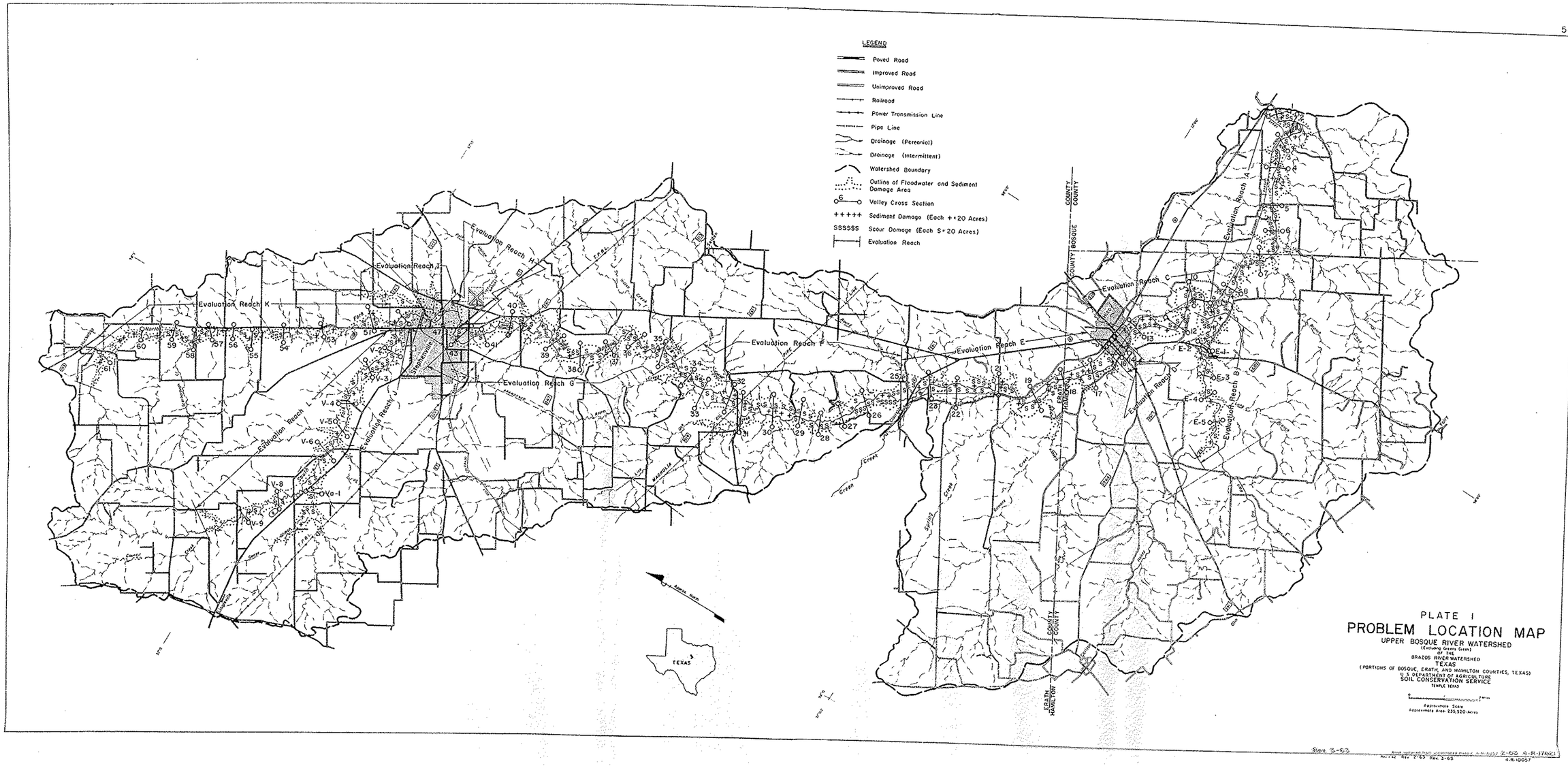


PLATE I

PROBLEM LOCATION MAP

UPPER BOSQUE RIVER WATERSHED
(Excluding Green Creek)
OF THE
BRAZOS RIVER WATERSHED
TEXAS
(PORTIONS OF BOSQUE, ERATH, AND HAMILTON COUNTIES, TEXAS)
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

Approximate Scale
Approximate Area: 235,520 Acres

Rev. 3-63

Base compiled from unannotated mosaic A-R-1955 2-62 4-R-17621
Rev. 4-62 Rev. 2-63 Rev. 3-63
4-R-19057

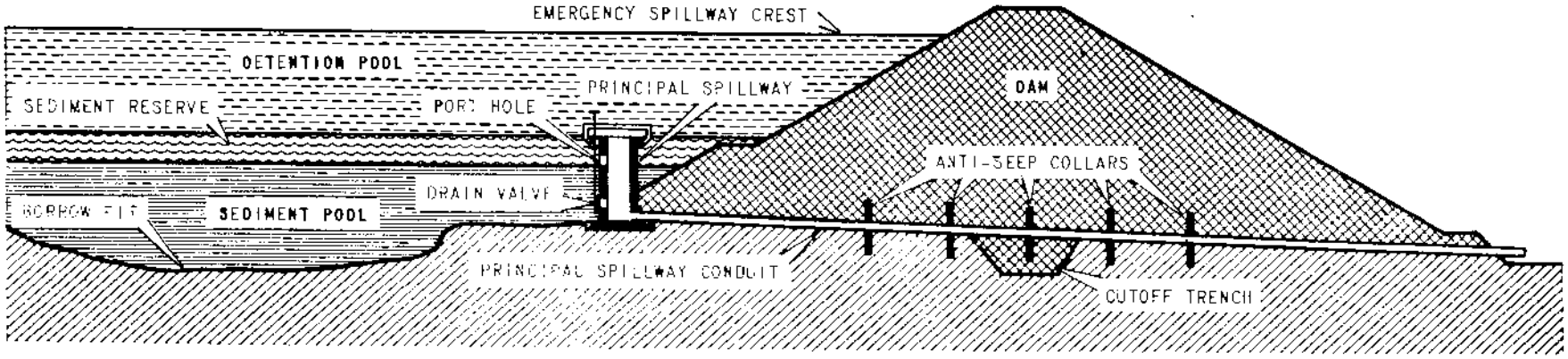


Plate 2

SECTION OF A TYPICAL FLOODWATER RETARDING STRUCTURE

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

Revised 10-31-60 A-L-10,071

Base from Aerial Photo No. DMC-16T-143

N

0 ½

Miles

Plate 3

URBAN BENEFIT AREA
HICO, TEXAS

100 YEAR FREQUENCY FLOOD
UPPER BOSQUE RIVER WATERSHED
Bosque, Erath, and Hamilton Counties, Texas

Rev. 3-63 4-R-17612

Base from Aerial Photo No. AXA-10W-167

N

0 ½

Miles

Plate 4

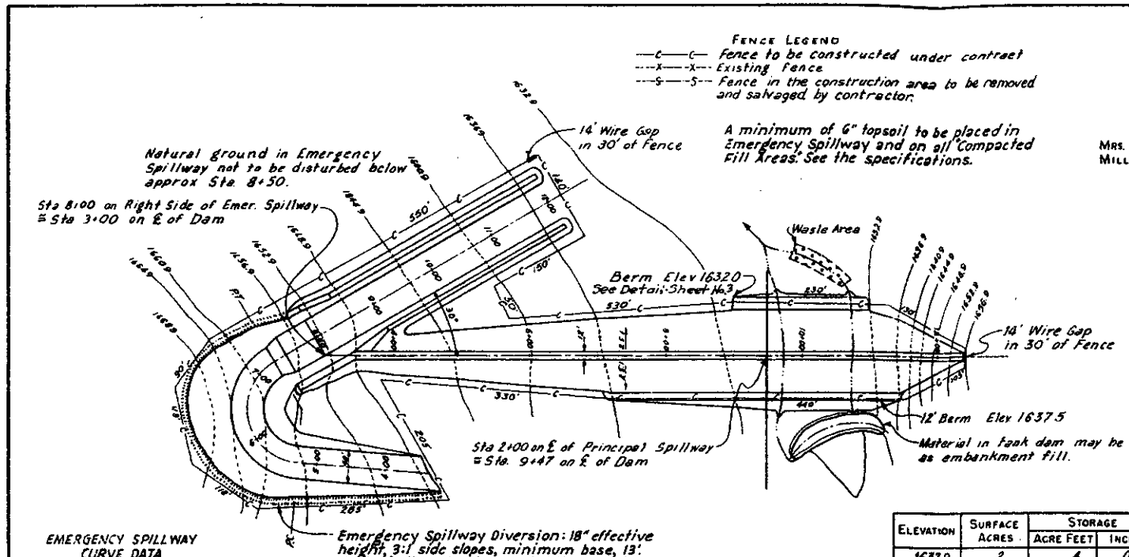
URBAN BENEFIT AREA
STEPHENVILLE, TEXAS

100 YEAR FREQUENCY FLOOD
UPPER BOSQUE RIVER WATERSHED
Bosque, Erath, and Hamilton Counties, Texas

Rev. 3-63 4-R-17613

FENCE LEGEND
—C—C— Fence to be constructed under contract
---X---X--- Existing Fence
---S---S--- Fence in the construction area to be removed and salvaged by contractor.

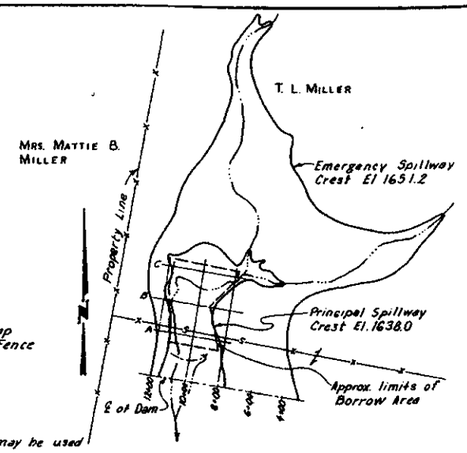
A minimum of 6" topsoil to be placed in Emergency Spillway and on all Compacted Fill Areas. See the specifications.



EMERGENCY SPILLWAY CURVE DATA
Δ = 144°00'
D = 71°37'
R = 80.35'
L = 201.0'
P.C. = Sta. 5+29
P.T. = Sta. 7+30

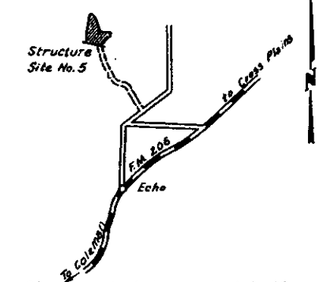
PLAN OF EMBANKMENT AND SPILLWAYS

0 100 200 300 400 500
SCALE IN FEET



GENERAL PLAN OF RESERVOIR

0 400 800 1200 1600
SCALE IN FEET



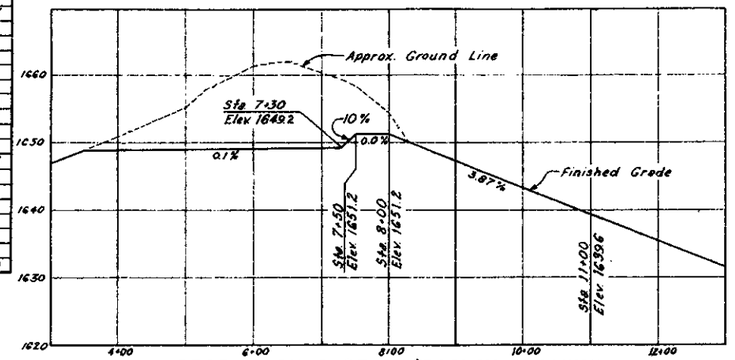
Structure located approximately 12 miles northeast of Coleman, Coleman County, Texas.

VICINITY MAP

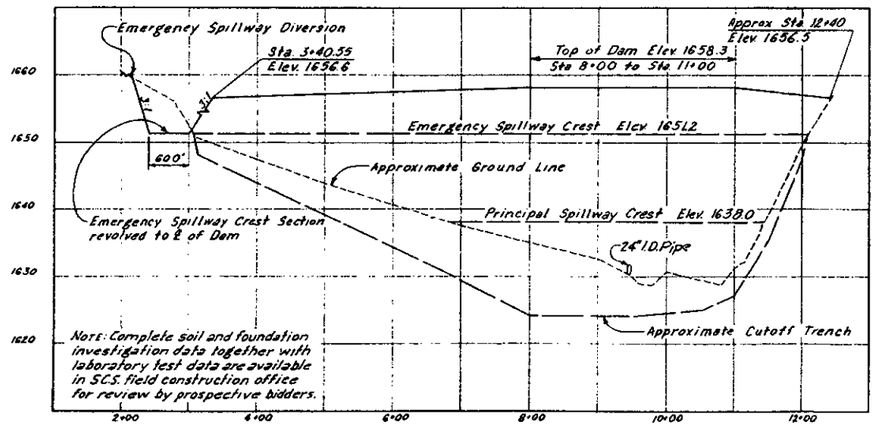
0 1 2 3 4
SCALE IN MILES

Elevation	Surface Acres	Storage Acre Feet	Storage Inches
1632.9	2	4	0.05
1636.9	6	20	0.27
1638.0	8	28	0.37
1640.9	14	60	0.80
1644.9	20	128	1.70
1648.9	29	226	3.00
1651.2	36.4	301	3.99
1652.9	42	368	4.88
1656.9	53	558	7.40
1660.9	64	792	10.51

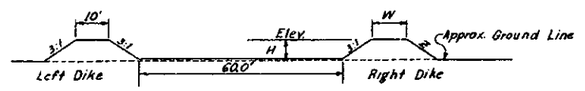
Top of Dam (Effective) Elev.	1656.5
Emergency Spillway Crest Elev.	1651.2
Principal Spillway Crest Elev.	1638.0
Sediment Pool Elev.	1638.0
Drainage Area, Acres	904
Sediment Storage, Acre Feet	32
Floodwater Storage, Acre Feet	269
Max. Emergency Spillway Cap., c.f.s.	1830



PROFILE ON ℄ OF EMERGENCY SPILLWAY



PROFILE ON ℄ OF DAM



Left Dike:
Approx. Sta. 7+75 to Sta. 8+00 Elev 1656.6 From Sta 8+00 to Sta 8+50, grade uniformly to H=3.0'. From Sta 8+50 to 12+00, H=3.0'.

Right Dike:
Approx. Sta 7+40 to Embankment Elev 1656.6, W=14.0', Z=2.5:1. From Embankment to Sta. 9+00 Transition Section. Sta 9+00 to Sta. 12+00 H=3.0', W=10.0', Z=3:1.

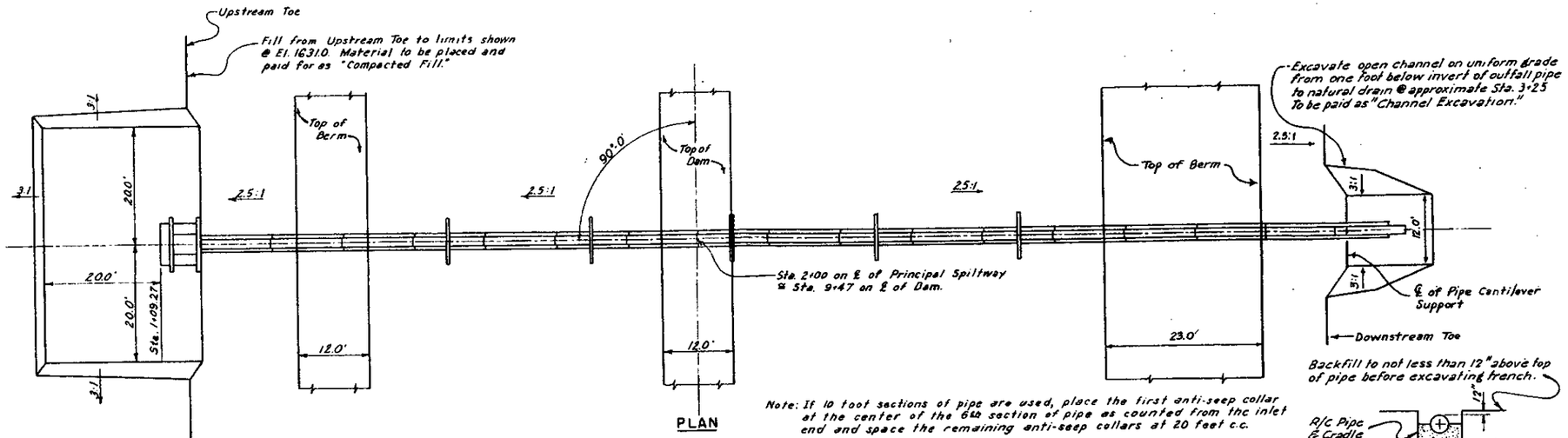
Note:
Material forming both dikes to be placed and paid for as "Compacted Fill."
Natural ground in Emergency Spillway not to be disturbed below approx. Sta 8+50

TYPICAL SECTION — EMERGENCY SPILLWAY

Plate 5
TYPICAL
FLOODWATER RETARDING STRUCTURE
GENERAL PLAN AND PROFILE

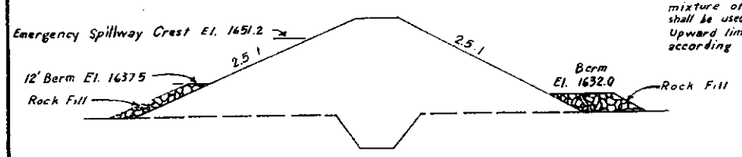
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed W.E.C.	3-61	Approved by:	
Drawn W.E.C. & H.R.T.	3-61	Title: Acting Assistant Administrator for Land and Water Resources	
Traced H.R.T.	3-61	Texas Conservation Engineer	
Checked W.E.C. & G.W.T.	4-61	Sheet No. 2 of 8 sheets	Drawing No. 4-E-15,357



SECTION

PRINCIPAL SPILLWAY



TYPICAL SECTION

Notes: No Formal Embankment Zoning is required. Selection of materials represented by Laboratory Curve No. 1, 3, and 4 shall be used in Cutoff Trench and center section of Embankment. The material represented by Laboratory Curve No. 2 shall be used in the outer shell. The mixture of rock and earth excavation from the emergency spillway shall be used in the upstream and downstream Berms. Upward limits of moisture will be determined by the Project Engineer according to the workability aspects of materials during construction.

MATERIALS					
LAB TEST		COMPACTION REQUIREMENTS			Lab. Curve
Modified		Min. Dry Density	Moisture Range Percent		
Max. Dry Den.	Opt'm Moist	Lbs. Per Cu Ft.	From	To	No.
119.5	12.5	107.2	13.0	UP	1
146.0	6.1	136.7	6.1	UP	2
126.1	10.9	113.9	10.9	UP	3
136.5	11.5	112.0	12.0	UP	4

If the material being placed in the fill contains ¼ inch or larger material in amounts differing from the percentages found in the laboratory sample, the minimum dry density and moisture requirement will be corrected for this variation.

EMBANKMENT DATA

Note: The detail above is planned for 12 foot sections of pipe. Section lengths of 10 feet may be used with invert of joints set on grade line as established above, utilizing 200 feet of pipe, ending at station 3+16. Section lengths in excess of 12 feet will not be permitted.

Plate 5A

TYPICAL

FLOODWATER RETARDING STRUCTURE

STRUCTURE PLAN AND SECTION

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	W.E.C.	3-61	Approved by:
Drawn	W.E.C & H.R.T.	3-61	
Traced	H.R.T.	3-61	
Checked	W.E.C & G.W.T.	4-61	Sheet No. 3 of 8 — Drawing No. 4-E-15,357

Site Numbers and Drainage Areas in Acres

No.	Area	No.	Area
1	2925	15	2771
*2	3296	16	4256
3	3834	17	13197
4	1568	18	4794
5	1248	19	5536
6	2611	20	1888
7	851	21	2886
8	2253	22	1491
*9	6381	23	1190
10	3411	24	5638
11	3565	25	4262
12	2496	26	1146
13	2874	27	13261
14	941	28	3610

* Exclusive of Area Controlled by Other Structures

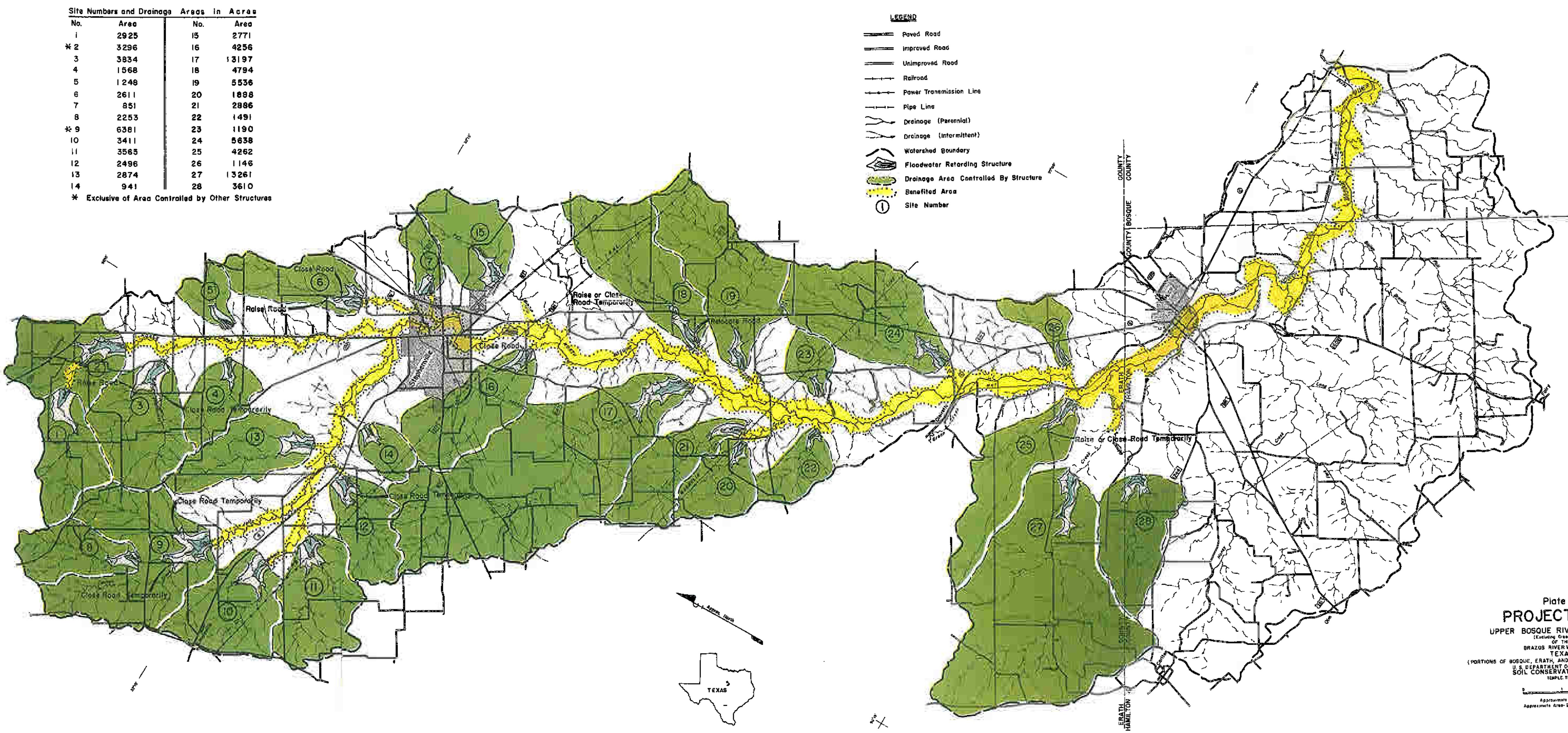


Plate 6

PROJECT MAP

UPPER BOSQUE RIVER WATERSHED
(Excluding Greens Creek)
OF THE
BRAZOS RIVER WATERSHED
TEXAS
(PORTIONS OF BOSQUE, ERATH, AND HAMILTON COUNTIES, TEXAS)
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

Approximate Scale
Approximate Area- 235,520-Acres

Base compiled from uncontrolled mosaic 4-R-16252 2-63 4-R-17622
Rev 1-62 Rev 2-63 4-R-10057