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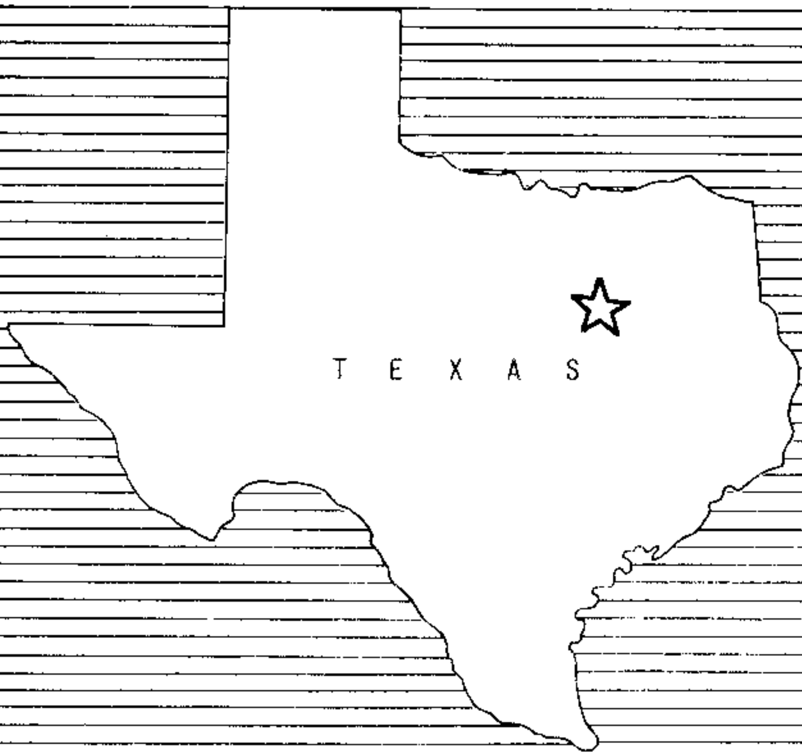
WORK PLAN

FOR WATERSHED PROTECTION AND FLOOD PREVENTION

TEHUACANA CREEK WATERSHED

McLennon, Hill and Limestone Counties, Texas



November 1958

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WATERSHED WORK PLAN AGREEMENT

between the

McLennan County Soil Conservation District
Local Organization

Navarro-Hill Soil Conservation District
Local Organization

Limestone-Falls Soil Conservation District
Local Organization

McLennan and Hill Counties Tehuacana Creek Water

Control and Improvement District No. 1

In the 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 assistance in preparing a plan for works of improvement for the Tehuacana Creek 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 by the Act of August 7, 1956 (Public Law 1018, 84th Congress; 70 Stat. 1088); 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 Tehuacana Creek Watershed, State of Texas, hereinafter referred to as the watershed work plan, which plan is annexed to and 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 will be installed, within 8 years, and operated and maintained substantially in accordance with the terms, conditions, and stipulations provided for therein.

It is mutually agreed that in installing and operating and maintaining the works of improvement described 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 $ 812,702 .)

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 and land treatment measures for flood prevention 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)
31 Floodwater Retarding Structures	0	100	2,297,782
11.7 Miles Channel Improvement	0	100	760,881

The Sponsoring Local Organization will pay all of the costs allocated to purposes other than flood prevention, and irrigation, drainage, and other agricultural water management.

4. The Service will bear the cost of all installation services applicable to works of improvement for flood prevention. (Estimated cost $ 1,015,475 .)

The Service will bear _____ percent of the cost of installation services applicable to works of improvement for agricultural water management and the Sponsoring Local Organization will bear ______ percent of the cost of such services. (Estimated cost $______________________.)

The Sponsoring Local Organization will bear the cost of all installation services applicable to works of improvement for nonagricultural water management. (Estimated cost $____________________.)

5. The Sponsoring Local Organization will bear the costs of administering contracts. (Estimated cost $ 16,000 .)

6. The Sponsoring Local Organization will obtain agreements from owners of not less than 50 percent of the land above each 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.

McLennan County Soil Conservation District
Local Organization

By Dave Simmons

Title Chairman

Date 4/29/59

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

adopted at a meeting held on April 14, 1959

Harry F. Holland, Jr.
(Secretary, Local Organization)

Date April 29, 1959

Navarro-Hill Soil Conservation District
Local Organization

By *C. M. Newton Jr*

Title *Chairman*

Date *4-29-59*

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

adopted at a meeting held on *4-24-59*.

H.R. Lively (acting)
(Secretary, Local Organization)

Date *April 29, 1959*

Limestone-Falls Soil Conservation District
Local Organization

By *Frank W. Mitchell*

Title *Chairman*

Date *4/29/59*

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

adopted at a meeting held on *4/15/59*

R.W. Gibbs
act (Secretary, Local Organization)

Date *4/29/59*

McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1
Local Organization

By D. T. James

Title Chist.

Date April 29th, 1959

The signing of this agreement was authorized by a resolution of the governing body of the McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1
Local Organization

adopted at a meeting held on April 15th, 1959

W. H. James
(Secretary, Local Organization)

Date April 29, 1959

____
Local Organization

By ______________________

Title ______________________

Date ______________________

The signing of this agreement was authorized by a resolution of the governing body of the ______________________
Local Organization

adopted at a meeting held on ______________________

____
(Secretary, Local Organization)

Date ______________________

Soil Conservation Service
United States Department of Agriculture

By ______________________
Administrator

Date ______________________

WORK PLAN

FOR

WATERSHED PROTECTION AND FLOOD PREVENTION

TEHUACANA CREEK WATERSHED
McLennan, Hill, and Limestone Counties, Texas

Prepared Under the Authority of the Watershed Protection and Flood Prevention Act. (Public Law 566, 83rd Congress; 68 Stat. 666 as Amended by Public Law 1018, 84th Congress; 70 Stat. 1088).

Prepared By: McLennan County Soil Conservation District
(Cosponsor)
Navarro-Hill Soil Conservation District
(Cosponsor)
Limestone-Falls Soil Conservation District
(Cosponsor)
McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1
(Cosponsor)

With Assistance By:

U. S. Department of Agriculture
Soil Conservation Service
November 1958

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SECTION 1

WATERSHED WORK PLAN

TEHUACANA CREEK WATERSHED
McLennan, Hill, and Limestone Counties, Texas
November 1958

SUMMARY OF PLAN

General Summary

The work plan for Tehuacana Creek watershed, Texas, was prepared by the McLennan County Soil Conservation District, Navarro-Hill Soil Conservation District, Limestone-Falls Soil Conservation District and the McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1, as the local cosponsoring organizations. Technical assistance was provided by the United States Department of Agriculture.

The watershed work plan covers an area of approximately 307 square miles, or 196,480 acres, in McLennan, Hill, and Limestone Counties, Texas. Approximately 57.2 percent of the watershed is cropland, 35.6 percent is grassland, 4.9 percent woodland, 0.9 percent Federally-owned land, and 1.4 percent is in miscellaneous uses such as stream channels, towns, roads, railroads, and gravel pits.

Federally-owned land in the watershed consists of 1,852 acres at James Connally Air Force Base.

The work plan proposes installation during an 8-year period a project for the protection and development of the watershed at a total estimated installation cost of $6,572,418. The share of this cost to be borne by Public Law 566 funds will be $4,212,882. The remaining $2,359,536 will be borne by local and other funds.

Land Treatment Measures

The cost for land treatment measures is estimated to be $1,669,578, of which the share to be borne by other than Public Law 566 funds is $1,530,834. It is estimated that $101,256 will be available from the Public Law 46 going program for technical assistance. The share to be borne by Public Law 566 funds, consisting entirely of accelerated technical assistance, is $138,744. The land treatment program will be installed over an eight-year period.

Structural Measures

The structural measures included in the plan consist of 31 floodwater retarding structures and 11.7 miles of channel improvement. The 31 structures will have a total capacity of 75,306 acre-feet of floodwater detention and sediment storage. The total cost of these measures is $4,902,840, of which the local share is $828,702 and the Public Law 566 share is $4,074,138. The local share of the cost of structural measures includes: land, easements, and rights-of-way, 98.1 percent, and administering contracts, 1.9 percent. The structural measures will be installed over a five-year period.

Damages and Benefits

The estimated average annual floodwater, sediment, flood plain erosion and indirect damage without the project is $399,760, computed at long-term price levels. The estimated average annual damage with the project installed, including land treatment and structural measures, is $52,374, a reduction of 86.9 percent.

The average annual primary benefits accruing to structural measures are $323,067, which are distributed as follows:

Floodwater damage reduction	$236,707
Sediment damage reduction	28,072
Flood plain erosion damage reduction	8,694
Indirect damage reduction	27,348
Benefits from changed land use	19,637
Benefits from outside project area	2,609

The ratio of the average annual benefit, $323,067, to the average annual cost of structural measures, $192,364, is 1.7 to 1.

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

Provisions for Financing Construction

The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 has powers of taxation and eminent domain under applicable state laws. This district will administer the contracts for the structural measures listed in the plan. Funds for financing the local share of the project will be raised by a proposed district-wide ad valorem tax.

Operation and Maintenance

Land treatment measures will be installed, operated, and maintained by the landowners and operators of the farms under agreement with the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts.

Under terms of an operations and maintenance agreement to be executed, the 31 floodwater retarding structures and 11.7 miles of channel improvement will be operated and maintained by the McLennan and Hill Couties Tehuacana Creek Water Control and Improvement District No. 1.

DESCRIPTION OF THE WATERSHED

Physical Data

Tehuacana Creek heads near the town of Penelope in southern Hill County and flows southward for approximately 21 miles to its confluence with the Brazos River, 5 miles east of the city of Waco, McLennan County, Texas. The principal tributaries are Brookeen, Rice, Elm, Little Tehuacana, Wolf, Roberts, Williams, and Tradinghouse Creeks. The area of the watershed is 307.00 square miles (196,480 acres).

The topography ranges from nearly level along the alluvial valley to steeply sloping in the upland areas. Elevations range from 380 feet to 720 feet above mean sea leval. The flood plain of Tehuacana Creek is well defined and consists of 18,922 acres, including 1,532 acres of stream channels. The flood plain as discussed here is the bottom land area inundated by the runoff from the 25-year frequency storm, based on gage records.

The watershed lies entirely within the Blackland Prairies Land Resource Area and is underlain by geological formations of the Taylor and Austin groups. Lying within this area are scattered outcrops of the Wolf City sand and Durango sand formations which give rise to soils of the Wilson and Crockett series that are locally called "greyland". These scattered areas are characterized by some post-oak timber and very slowly permeable soils. The majority of the watershed, however, is underlain by sandy shales and marly clays of the Taylor group which give rise to clay soils of the Houston, Houston Black and Trinity series. These soils are deep and slowly permeable. Near the north boundary of the watershed, there is an outcrop of the Austin chalk formation and some soils of the Austin series which are moderately deep to shallow and moderately permeable. The Taylor formation comprises approximately 95 percent of the watershed with the remaining 5 percent consisting of the Austin formation. The soils throughout the watershed are in fair to poor physical condition.

The overall land use for the watershed is as follows:

Land Use	Acres	Percent
Cropland	112,301	57.2
Grassland	69,996	35.6
Woodland	9,620	4.9
Federally-Owned Land	1,852	0.9
Miscellaneous 1/	2,711	1.4
Total	196,480	100.0

1/ Includes road, highway, and railroad rights-of-way; urban areas; etc.

Land use in the flood plain is as follows: 57.1 percent in cultivation; 26.2 percent in pasture; 14.1 percent in woods; and 2.6 percent in miscellaneous uses.

The Rolling Deep upland site is the only range site in the watershed. The soils in this site are the Wilson-Houston Series on slopes of 3 to 5 percent. The original climax vegetation consisted of big bluestem, Indiangrass, little bluestem, switchgrass, and eastern grama grass. The present cover condition in this range site is good to fair.

The mean annual rainfall is 35.0 inches as recorded at U. S. Weather Bureau gages at Waco, Hillsboro, and Mexia, over a 20-year period. The monthly average ranges from 1.76 inches in August to 4.46 inches in May. Average temperatures range from 85 degrees Fahrenheit in the summer to 47 degrees in the winter. The normal frost-free period of 244 days extends from March 11 to November 10.

Water for livestock and rural domestic use is obtained from surface ponds and wells.

Economic Data

The watershed is well suited to crop production and supports a rather intensive agriculture. Cash crop production predominates, with cotton, corn, grain sorghum, and small grains being the most important crops. There are also several beef cattle and dairy enterprises within the watershed. The average size farming unit is approximately 170 acres. Approximately 60 percent of the farm operators who live on the farm supplement their income with outside employment in nearby cities and military installations. A large gravel pit with annual operations in excess of one million dollars is located in the southern part of the flood plain.

West, population 2,130, Elm Mott, population 275, Axtell, population 220, Leroy, population 250, Birome, population 50, and Hoen, population 40, are wholly or partially within the watershed. Waco, population 100,000, which is the principal local market for farm products, is only a few miles from the watershed. Fort Worth, 89 miles north of Waco, is the major market for livestock, though many animals are sold and slaughtered in Waco. These cities provide excellent marketing, educational, cultural, recreational, and medical facilities for the people in the area

The watershed is adequately served by 464 miles of roads, 114 of which are paved (U. S. Highways 81, 77, and 84, State Highways 31, and 6, Farm to Market Roads 308,737, and 939). Adequate rail facilities are provided by four railroads.

WATERSHED PROBLEMS

Floodwater Damage

Flooding occurs frequently on Tehuacana Creek and causes severe damage. During the 20-year period, 1923 - 1942, there were 31 major floods which inundated more than half of the flood plain (figure 1), as well as 39 smaller floods.

Floodwater damage - Tehuacana Creek - Flood of April 23, 1957

Sediment and scour damage - Tehuacāna Creek - Flood of May 11 & 12, 1953

Road and bridge damage - Tehuacana Creek - Flood of May 11 & 12, 1953

Upland erosion damage - Tehuacana Creek - Rains of May 11 & 12, 1953

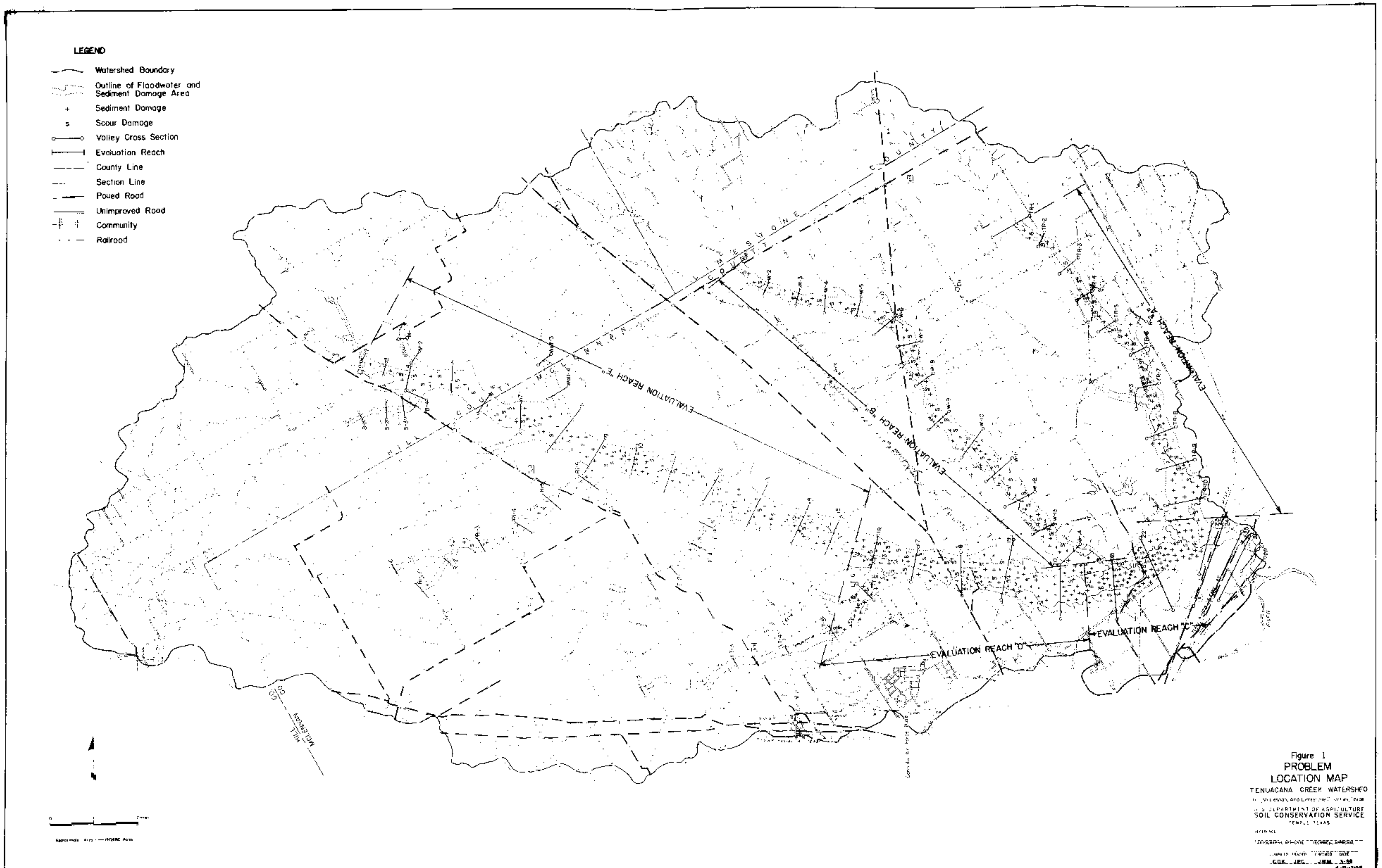


Figure 1
PROBLEM
LOCATION MAP
TENUACANA CREEK WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

4-R-13198

For the floods experienced during the period studied, the total direct agricultural and nonagricultural floodwater damages under present conditions were estimated to average $294,895 annually at long-term price levels, of which $239,766 is crop and pasture damage, $20,796 is other agricultural damage, and $34,333 is nonagricultural such as damage to roads, bridges, railroads, and gravel pits. Indirect damage such as interruption of travel, rerouting of school bus and mail routes, losses sustained by business in the area, and similar losses are estimated to average $36,342 annually.

The Soil Conservation Service has published a special storm report describing the effects of the storm of May 11 - 12, 1953 on the Tehuacana Creek watershed. The entire flood plain was inundated by the floodwaters from this storm. This one flood alone caused an estimated $898,300 damage, at 1952 prices. Similar recent floods occurred in May 1956, April and May 1957, and May and August 1958.

Sediment Damage

Damage by overbank deposition is moderate to severe in the watershed. Erosion in the upland areas of the watershed has resulted in deposition of fine textured silty clays and clays with some thin deposits of fine sand. The productive capacity has been reduced from 10 to 50 percent on an estimated 10,009 acres of flood plain by this process. The area affected by overbank deposition is as follows:

Evaluation Reach	Acres Damaged: Damaged 10 percent	Damaged 20 percent	Damaged 30 percent	Damaged 40 percent	Damaged 50 percent	Total
(Figure I)						
A	52	183	239	670	0	1,144
B	422	395	336	356	0	1,509
C	868	341	708	242	0	2,159
D	530	384	771	216	35	1,936
E	304	594	1,646	717	0	3,261
Total	2,176	1,897	3,700	2,201	35	10,009

The estimated average annual monetary damage by overbank deposition is $57,270 at long-term price levels.

Erosion Damage

Erosion rates in the upland areas of the watershed are moderate to high. The northern half of the watershed has high erosion rates due to steep slopes, a predominance of row-crop farming, and inadequate conservation treatment. The erosion rates are lower in the southern half of the watershed since more land is in pasture and slopes are generally less than two percent.

Sheet erosion is the major process in the upland areas of the watershed, accounting for 93 percent of the annual gross erosion. Gully and streambank erosion account for 7 percent. The average annual rate of upland gross erosion is 4.04 acre-feet per square mile. This rate varies from 4.82 acre-feet per square mile in the northern half of the watershed to 3.20 acre-feet per square mile in the southern half of the watershed.

Flood plain scour erosion is moderate in the watershed. It is estimated that 3,305 acres are being damaged annually by this process. The productive capacity of the flood plain soil has been reduced from 10 to 40 percent by scour. Flood plain scour damage by evaluation reaches is as follows:

Evaluation Reach	Acres Damaged: Damaged 10 Percent	Damaged 20 Percent	Damaged 30 Percent	Damaged 40 Percent	Total
(Figure 1)					
A	288	118	18	0	424
B	505	87	60	13	665
C	155	198	74	0	427
D	450	101	71	43	665
E	661	306	130	27	1,124
Total	2,059	810	353	83	3,305

The estimated average annual monetary damage by flood plain scour is $11,253 at long-term price levels.

Problems Relating to Water Management

There are several Water Control and Improvement Districts in the area which are organized to provide adequate water supply for the towns of Leroy, Elm Mott, Axtell, Hoen, Lacy-Lake View, and Hallsburg. This water comes from deep wells drilled in the Trinity group.

There is little activity relative to drainage, irrigation, or other agricultural water management in the watershed. Two landowners in reach C (figure 1) have been granted appropriations for a total of 725 acre-feet of water for non-consumptive use by the State Board of Water Engineers. Several landowners are irrigating from wells.

The planned works of improvement will have no detrimental effects on any water supply in the watershed.

EXISTING OR PROPOSED WORKS OF IMPROVEMENT

The Tehuacana Creek watershed is served by Soil Conservation Service work units at Waco, West, and Hubbard assisting the McLennan County, Navarro-Hill and Limestone-Falls Soil Conservation Districts. These work units have assisted farmers in preparing 557 basic and progressive soil and water conservation plans on 103,449 acres, representing 54 percent of the agricultural land within the watershed, and have given technical guidance in establishing and maintaining planned measures.

Major interest in flood prevention by people within the watershed dates back to the early thirties when a study of channelization from the McLennan-Hill county line to the mouth of Tehuacana Creek was made. Nothing ever came of this because many of the landowners felt there was a better way of doing it. The thinking of these people was probably influenced to a great extent by the low prices received for farm products at that time. Only minor efforts have been made to prevent or control floods in the Tehuacana Creek watershed. A few attempts to control floods by individual landowners by enlargement and straightening of stream channels and construction of levees have been made with little effect on flood damage.

The New Mart Lake has been used for municipal water supply in the past but is presently being used only as a standby supply and for recreational purposes. It will be converted to a floodwater retarding structure.

The Corps of Engineers is authorized by the Flood Control Act of 1954 to construct six reservoirs, in addition to the previously authorized Whitney and Belton Reservoirs, in the Brazos River Basin. The Whitney and Belton Reservoirs have been constructed; Waco Reservoir on the Bosque River is under construction; and the Proctor Reservoir on the Leon River and Lampasas Reservoir on the Lampasas River are in the advanced planning stage. None of these reservoirs will affect the Tehuacana Creek watershed except as they may have a backwater effect in reducing peak flows in the Brazos River.

The Public Law 566 project will complement the Corps of Engineers Reservoirs by providing needed protection to flood plain lands on Tehuacana Creek which would not be provided by the Corps' projects. Benefits to flood plain of the Brazos River below the confluence with Tehuacana Creek were computed from the reduction in damages remaining after all of the Corps' projects are constructed.

The Bureau of Reclamation, USDI, is currently making a study of the Brazos River Basin to determine feasibility of irrigation along the mainstem and its tributaries. The Tehuacana Creek watershed is within the area covered by this investigation.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures for Watershed Protection

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, such as is now being carried out by the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts, is necessary for a sound 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

Terracing, contour cultivation and stubble mulching.

Conservation crop rotation - Hubam clover for soil improvement.

land use. Emphasis will be placed on accelerating the establishment of land treatment practices which have a measurable effect on the reduction of floodwater, sediment, and erosion damages.

Approximately 113,907 acres of the total watershed area of 196,480 acres lie above the planned floodwater retarding structures. Land treatment is especially important for protection of these watershed lands to support and supplement the structural measures. Land treatment constitutes the only planned measures on the remaining upland area. Land treatment measures on the 17,390 acres of flood plain lands are also important in reducing floodwater and erosion damages.

The amounts and estimated costs of the measures that will be installed by the landowners and operators are shown in table 1. The estimated total cost of planning and installing these measures is $1,669,578, including $138,744 for the acceleration of technical assistance during the 8-year installation period to help owners and operators to plan and speed up the application of conservation practices. Landowners and operators will maintain these measures in accordance with provisions of the farmer-district cooperative agreements with the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts.

Land treatment measures will decrease erosion damage and sediment production from fields and pastures by providing improved soil-cover conditions. These measures include conservation cropping systems, cover cropping, use of rotation hay and pasture, crop residue utilization, gully stabilization, and pasture planting to establish good cover on grassland and formerly cultivated lands. They also include brush control to allow grass to improve and replace the poor brush cover; construction of farm ponds to provide adequate watering places to prevent cover destroying seasonal concentrations of livestock; and proper use and deferred and rotation grazing of grass land to provide improvement, protection, and maintenance of grass stands. These measures also effectively improve soil conditions which allow rainfall to soak into the soil at a more rapid rate.

In addition to the soil improvement and cover measures, land treatment includes contour farming, terracing, diversion construction, and the waterway development necessary to serve these measures, all of which have a measurable effect in reducing peak discharge by slowing the runoff of water from watershed lands. These measures also help the soil improvement and cover measures to reduce erosion damage and sediment production.

Structural Measures

A system of 31 floodwater retarding structures and 11.7 miles of channel improvement will be installed in the watershed to provide needed protection for flood plain land that cannot be attained by the land treatment measures described above.

This system of structures, when installed, will temporarily detain runoff from 58 percent of the total watershed. The 31 floodwater retarding

TABLE 1 - ESTIMATED PROJECT INSTALLATION COSTS 1/

Tehoacana Creek Watershed, Texas
Price Base: 1958

Installation Cost Item	Unit	No. to be Applied Non-Federal Land	Estimated Cost: Public Law 566 Funds (dollars)	Other Funds (dollars)	Total (dollars)
LAND TREATMENT FOR					
Watershed Protection					
Soil Conservation Service					
Cropland					
Contour Farming	Acre	21,401	-	42,802	42,802
Cover Cropping	Acre	24,858	-	248,580	248,580
Conservation Cropping System	Acre	33,732	-	101,196	101,196
Crop Residue Utilization	Acre	29,867	-	59,734	59,734
Diversion Construction	Mile	26	-	8,580	8,580
Rotation Hay and Pasture	Acre	4,939	-	49,390	49,390
Stabilization Measures	Each	29	-	43,500	43,500
Terracing	Mile	1,447	-	305,317	305,317
Waterway Deoelopment	Acre	1,515	-	90,900	90,900
Pasture					
Brush Control	Acre	5,487	-	103,220	103,220
Deferred Grazing	Acre	780	-	780	780
Pasture Planting	Acre	14,923	-	179,076	179,076
Pond Construction	Each	288	-	129,600	129,600
Proper Use	Acre	27,537	-	27,537	27,537
Rotation Grazing	Acre	14,674	-	29,348	29,348
Range					
Brush Control	Acre	476	-	8,568	8,568
Deferred Grazing	Acre	813	-	813	813
Range Seeding	Acre	91	-	637	637
Technical Assistance			138,744	101,256	240,000
SCS Subtotal			138,744	1,530,834	1,669,578
TOTAL LAND TREATMENT			138,744	1,530,834	1,669,578
STRUCTURAL MEASURES					
Soil Conservation Service					
Floodwater Retarding Structures	No.	31	2,297,782	-	2,297,782
Channel Improvement	Mile	11.7	760,881	-	760,881
Subtotal - Construction			3,058,663	-	3,058,663
INSTALLATION SERVICES					
Soil Conservation Service					
Engineering Service			611,732	-	611,732
Other			403,743	-	403,743
SCS Subtotal			1,015,475	-	1,015,475
Subtotal - Installation Services			1,015,475	-	1,015,475
OTHER COSTS					
Land, Easements, and R/W			-	812,702	812,702
Administration of Contracts			-	16,000	16,000
Subtotal - Other			-	828,702	828,702
TOTAL STRUCTURAL MEASURES			4,076,138	828,702	4,902,840
TOTAL PROJECT			4,212,882	2,359,536	6,572,418
SUMMARY					
Subtotal SCS			4,212,882	2,359,536	6,572,418
TOTAL PROJECT			4,212,882	2,359,536	6,572,418

1/ No works of improvement to be installed on Federal lands. (James Connally Air Force Base).

November 1958

structures have floodwater detention capacity to detain an average of 6.04 inches of runoff from the watershed area above them. This is the equivalent of 3.50 inches of runoff from the entire 196,480-acre watershed.

Figure 2 shows a section of a typical floodwater retarding structure. Figure 3 shows a typical improved channel section. The location of the structural measures are shown on the Planned Structural Measures map, figure 4. The 11.7 miles of channel improvement will provide adequate channel capacity for release flows from the floodwater retarding structures, plus capacity to afford additional protection from runoff from the uncontrolled area. Of this total, 2.6 miles of channel will be cleared and grubbed only, with the remaining 9.1 miles requiring enlargement and straightening of the existing channel. Channel clearing only will start at the confluence of Tehuacana Creek and the Brazos River and will end at the confluence of Tehuacana and Tradinghouse Creeks. Enlargement and straightening of Tehuacana Creek will start at the confluence of Tehuacana and Tradinghouse Creeks and end at the present confluence of Tehuacana and Cottonwood Creeks.

Site 27, known as New Mart Lake will be converted into a floodwater retarding structure by lowering the present water level 2 feet, constructing a new emergency spillway, and raising the top of the dam 0.5 foot above its original height. The lake was constructed by the city of Mart in 1925 for municipal water supply. A deep well has been used for water supply since 1951, with the lake serving only as a standby supply.

The total estimated cost of establishing the structural works of improvement is $4,902,840, of which $828,702 will be borne by local interests and $4,074,138 will be borne by Public Law 566 funds (table 1).

The estimated annual equivalent cost of installation, $172,864, with an estimated annual operation and maintenance cost of $19,500 makes a total annual cost of $192,364.

Sufficient detention storage can be developed at all structure sites to make possible the use of vegetative spillways, thereby effecting a substantial reduction in cost over concrete or a similar type of spillway All applicable state water laws will be complied with in the design and construction of the floodwater retarding structures.

BENEFITS FROM WORKS OF IMPROVEMENT

The general location of the areas to which the benefits from the combined program of land treatment and structural measures will accrue are presented in the following table:

	Evaluation Reach (figure 1)					
	A	B	C	D	E	Total
Average Annual Area Flooded						
Without Project - (acres)	2,701	3,354	8,120	6,489	8,074	28,738
With Project - (acres)	1,027	880	616	932	2,475	5,930
Percent Reduction	62	74	92	86	69	79

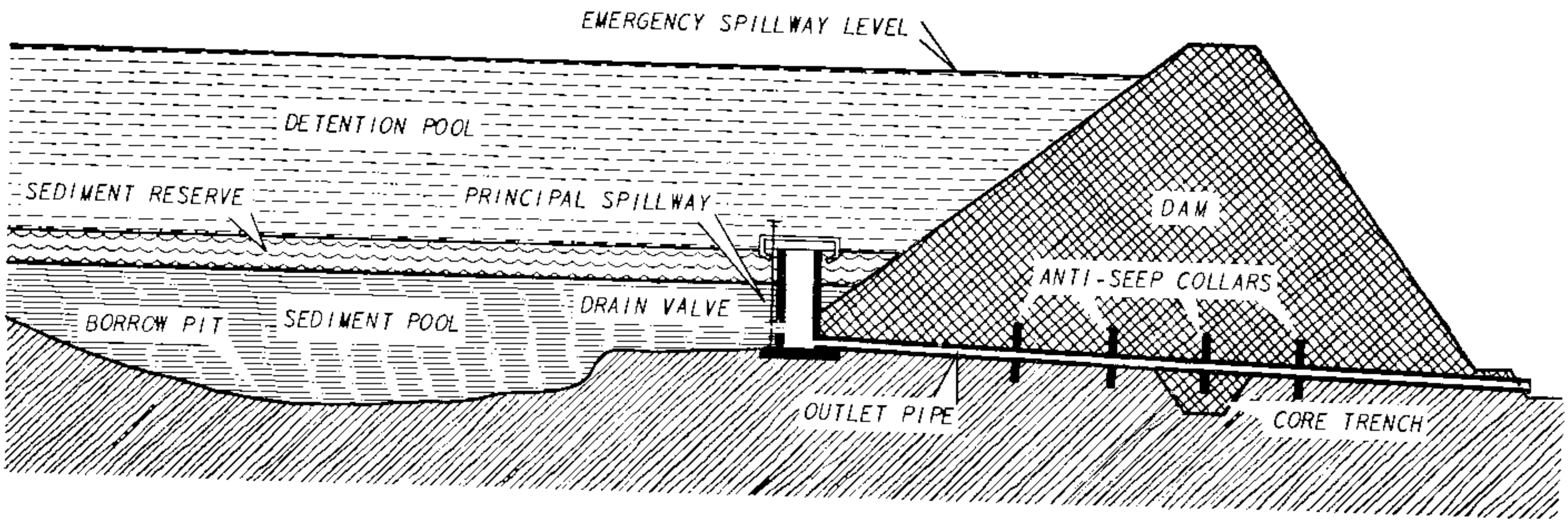


Figure 2

SECTION OF A TYPICAL FLOODWATER RETARDING STRUCTURE

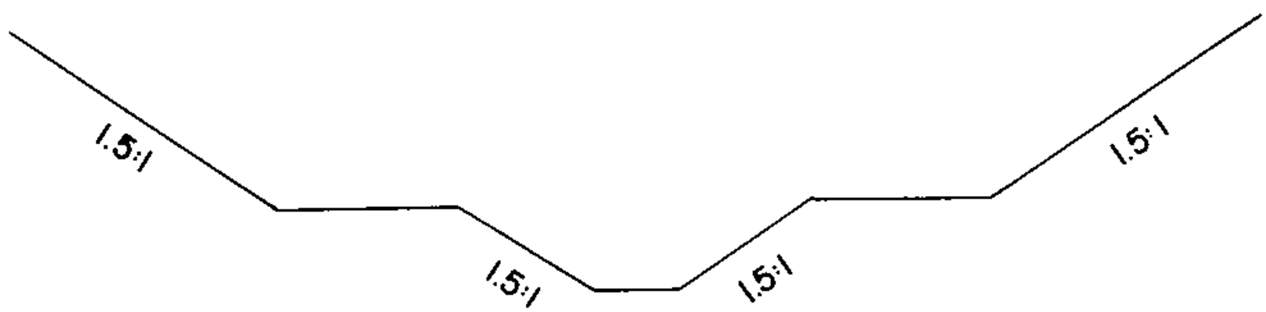


Figure 3

TYPICAL SECTION OF IMPROVED CHANNEL

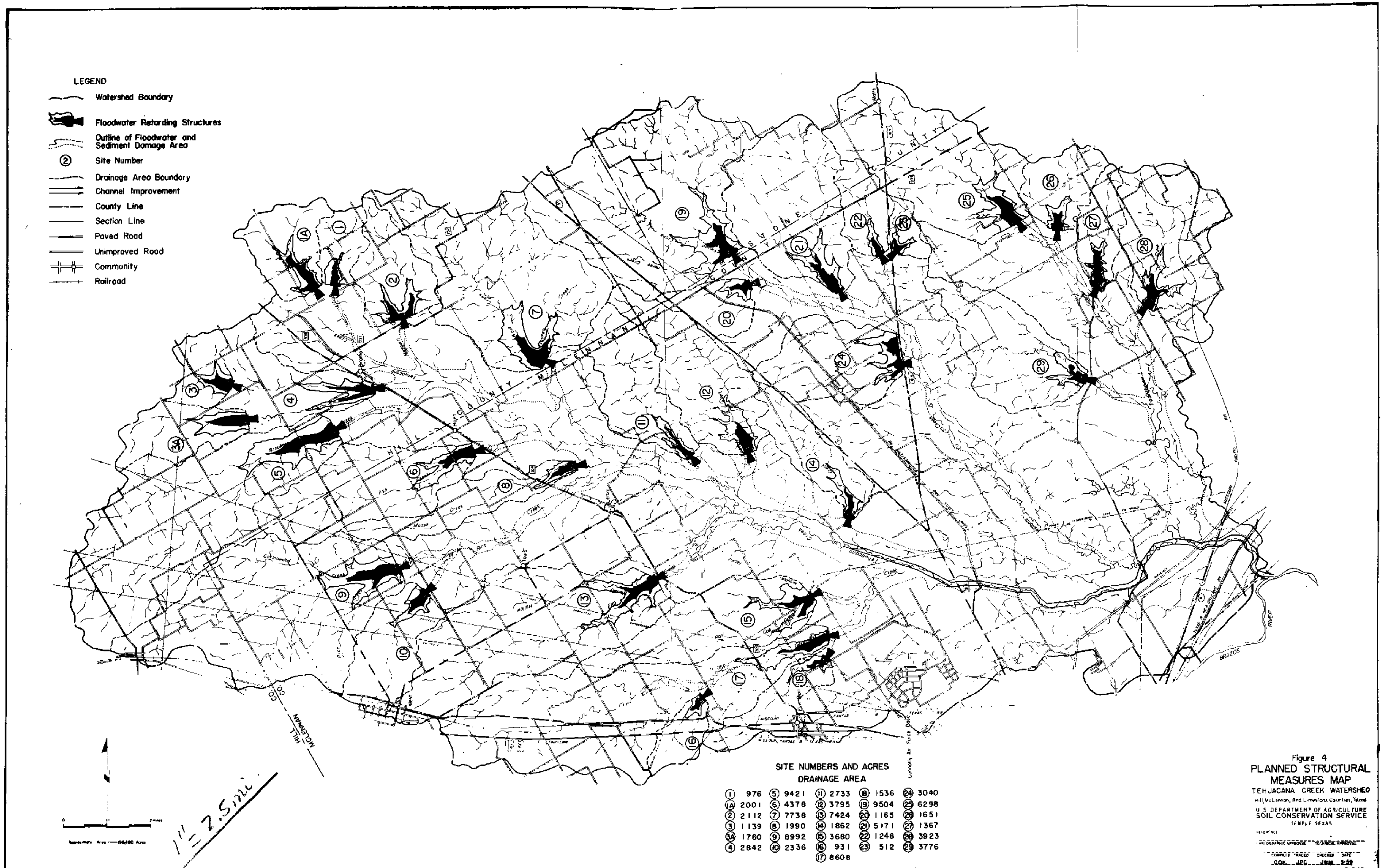


Figure 4
PLANNED STRUCTURAL MEASURES MAP
TEHUACANA CREEK WATERSHED
Hill, McLennan, And Limestone Counties, Texas
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE TEXAS

	Evaluation Reach (figure 1) - Continued					
	A	B	C	D	E	Total
Average Annual Area Subject to Recurrent Flooding						
With Project - (acres)	282	234	89	240	661	1,506
Area Flooded by Largest Storm						
Without Project - (acres)	1,721	2,352	4,012	2,950	5,245	16,280
With Project - (acres)	1,028	1,123	2,420	1,572	2,900	9,043
Percent Reduction	40	52	40	47	45	44
Average Annual Damages						
Without Project - (dollars)	38,548	39,986	137,167	52,632	131,427	399,760
With Project -(dollars)	9,000	5,973	6,971	4,159	26,271	52,374
Percent Reduction	77	85	95	92	80	87

The evaluation storm series for the period 1923 through 1942 contained 70 storms which would cause inundation of the flood plain under present conditions at the smallest channel cross section. The following table shows a comparison of the number of storms in the evaluation series which caused floodwater damage, and the number which inundated more than half of the flood plain with and without the project for each evaluation reach.

	Evaluation Reach (figure 1)				
	A	B	C	D	E
Floods in Evaluation Series (No.)					
Without Project	70	65	70	70	70
With Project	65	59	20	64	70
Major Floods in Evaluation Series (No.)					
Without Project	28	28	41	45	28
With Project	4	0	2	1	0

The 10,009 acres damaged by overbank deposition and the 3,305 acres damaged by flood plain scour (table 4) should be rendered productive again after they have been protected from flooding and adapted soil improving crop rotations have been established. A monetary reduction of 80 percent in sediment damage will occur after the installation of a complete program with 31 percent resulting from land treatment measures and the remaining 49 percent from structural measures. A monetary reduction of 89 percent in scour damage will occur after the installation of the complete program, with 12 percent due to land treatment and the remaining 77 percent attributed to structural measures.

The installation of the planned land treatment program can be expected to reduce the total annual upland gross erosion in the watershed from 1,129 acre-feet to 780 acre-feet, a reduction of 31 percent.

The estimated average annual floodwater, sediment, erosion, and indirect damages within the watershed will be reduced from $399,760 to $52,374, a reduction of 86.9 percent. Approximately 92.2 percent, $300,821, of the expected reduction in the average annual damage would result from the system of floodwater retarding structures and channel improvement.

Damage reduction benefits by type for each evaluation reach (figure 1) are indicated in the following table:

Benefit From Reduction in Damage

Type of Damage	Evaluation Reach A: Total Project	A: Structural Measures	Evaluation Reach B: Total Project	B: Structural Measures
	(dollars)	(dollars)	(dollars)	(dollars)
Crop and Pasture	16,254	15,023	18,206	16,929
Other Agricultural	2,621	2,269	4,073	3,583
Nonagricultural	2,687	2,293	3,658	3,209
Overbank Deposition	4,452	2,452	3,839	2,254
Flood Plain Scour	848	720	1,145	991
Indirect	2,686	2,276	3,092	2,697
Total	29,548	25,033	34,013	29,663
Percent of Total Damage Reduction by Structural Measures		84.72		87.21
Percent of Total Damage Reduction by Land Treatment Measures		15.28		12.79

Type of Damage	Evaluation Reach C: Total Project	C: Structural Measures	Evaluation Reach D: Total Project	D: Structural Measures
	(dollars)	(dollars)	(dollars)	(dollars)
Crop and Pasture	95,164	87,946	25,185	23,491
Other Agricultural	1,932	1,707	5,931	5,280
Nonagricultural	4,000	3,533	6,230	5,574
Overbank Deposition	14,595	9,623	5,388	3,446
Flood Plain Scour	2,669	2,374	1,332	1,181
Indirect	11,836	10,518	4,407	3,897
Total	130,196	115,701	48,473	42,869
Percent of Total Damage Reduction by Structural Measures		88.87		88.44
Percent of Total Damage Reduction by Land Treatment Measures		11.13		11.56

Benefit From Reduction in Damage - Continued

Type of Damage	E: Total Project (dollars)	E: Structural Measures (dollars)	Total All Reaches: Total Project (dollars)	Total All Reaches: Structural Measures (dollars)
Crop and Pasture	54,160	48,553	208,969	191,942
Other Agricultural	5,352	4,494	19,909	17,333
Nonagricultural	14,520	12,823	31,095	27,432
Overbank Deposition	17,552	10,297	45,826	28,072
Flood Plain Scour	4,012	3,428	10,006	8,694
Indirect	9,560	7,960	31,581	27,348
Total	105,156	87,555	347,386	300,821
Percent of Total Damage Reduction by Structural Measures		83.26		86.60
Percent of Total Damage Reduction by Land Treatment Measures		16.74		13.40

November 1958

Owners and operators of flood plain lands say that if adequate flood protection is provided, they will restore land now in pasture or meadow to crops. All of this land was in cultivation at one time, but is now used chiefly for hay or pasture, because of the frequency of flooding. It is estimated that net income from such restoration of land to former productivity will amount to $55,089 (long-term price levels) annually. This loss from the original production has been considered a crop and pasture damage and its restoration a benefit in table 7. A smaller acreage, now largely in woods, will be cleared and used for improved pasture and crops. The average annual benefit from this change in land use, after deduction of associated costs and discounting for time needed for development, is estimated at $19,637. No increases in the total acreage of allotment crops as a result of the project are included in the estimate of benefits. There is a shift of 975 acres of cotton from the sites of structural measures to flood plain lands. However, the reduced value of production within structural sites has been considered in the development of project costs.

The total flood prevention benefits as a result of structural measures are estimated to be $323,067 annually.

A reconnaissance study by the Fish and Wildlife Service, USDI, indicates that, generally, either fish and wildlife resources will be benefited or not materially affected by the watershed protection and flood prevention measures planned. No fish and wildlife benefits were considered in project justification.

COMPARISON OF BENEFITS AND COSTS

The average annual cost of the structural measures (converted from total installation cost, plus operation and maintenance cost) is estimated to be $192,364. When the project is installed it is expected to produce average annual benefits of $323,067. The project, therefore, will produce benefits of $1.68 for each dollar of cost.

In addition, there are other benefits which will accrue from the project, such as improved wildlife habitat, increased opportunity for recreation and a sense of security, none of which have been used for project justification.

ACCOMPLISHING THE PLAN

Federal assistance for carrying out the works of improvement on non-Federal land, as described in this work plan, will be provided under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Stat. 666, as amended by Public Law 1018; 84th Congress; 70 Stat. 1088).

Land Treatment Measures

The land treatment measures, itemized in table 1, will be established by farmers over an 8-year period in cooperation with the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts which are giving assistance in the planning and application of these measures under their going program.

The 8-year installation period was considered justified because the present high level of off-farm employment, brought about by the recent drought and unusually favorable opportunities for such employment, will temporarily retard the land treatment program. The long-time effects will be to increase the financial ability of landowners and operators to accomplish these measures, but certain measures will have to be deferred. Technical assistance will be accelerated with Public Law 566 funds to assure application of the planned measures within the 8-year installation period for the project.

The governing bodies of the McLennan County, Navarro-Hill, and the Limestone-Falls Soil Conservation Districts will assume aggressive leadership in getting an accelerated land treatment program under way, with the assistance of the McLennan and Hill Counties, Tehuacana Creek Water Control and Improvement District No. 1 in arranging for meetings according to a definite schedule. By this means and by individual contacts, the landowners within the watershed will be encouraged to adopt and carry out soil and water conservation plans on their farms. District-owned equipment will be made available to the landowners in accordance with existing arrangements for equipment usage in the districts. The soil conservation district governing bodies will make, or cause to be made, periodic inspections of the completed conservation measures within the watershed. The Soil Conservation Service will assign additional technicians and aids to the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts to assist landowners and operators cooperating with the districts in accelerating the preparation and application of soil, plant, and water conservation plans.

The Extension Service will assist the educational phase of the program by conducting general information and local farm meetings, preparing press, radio, and television releases, and using other methods of getting information to landowners and operators in the Tehuacana Creek watershed. This activity will help to get both the land treatment practices and the structural measures for flood prevention carried out.

The soil and water conservation loan program of Farmers Home Administration is available to all eligible individual 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 FHA clients will be encouraged to cooperate in the program.

The County ASC committees will cooperate with the governing bodies of the soil conservation districts by selecting and providing financial assistance for those ACPS practices which will accomplish the conservation objectives in the shortest possible time.

Structural Measures for Flood Prevention

The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 has the right of eminent domain under applicable state law and will obtain the necessary land, easements, and rights-of-way; provide necessary legal, administrative, and clerical personnel, facilities, supplies, and equipment to advertise, award, and administer contracts; and determine the legal adequacy of easements, permits, etc., for the construction of the 31 floodwater retarding structures and 11.7 miles of channel improvement included in the plan. Funds for the local share of the project costs including land, easements, rights-of-way, and administration of contracts will be raised through a proposed district-wide ad valorem tax.

All of the proposed structural works of improvement are considered to be one construction unit.

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

Fiscal Year	Measure	P.L. 566 Funds	Other Funds	Total
1st	Sites 25 through 29 and land treatment	424,263	265,494	689,757
2nd	Sites 19 through 24 and land treatment	670,783	298,981	969,764
3rd	Sites 6,7,8,11,12,13,14, and land treatment	802,379	367,301	1,169,680
4th	Site 15,16,17,18, channel improvement, and land treatment	1,403,009	374,117	1,777,126
5th	Sites 1,1A,2,3,3A,4,5,9,10, and land treatment	860,419	479,578	1,339,997
6th	Land treatment	17,343	191,355	208,698
7th	Land treatment	17,343	191,355	208,698
8th	Land treatment	17,343	191,355	208,698
	Total	4,212,882	2,359,536	6,572,418

This schedule will 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.

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

1. Adequate land treatment in the drainage area above structures has been installed.

2. All land, easements, and rights-of-way have been secured or a written statement is furnished by the McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 that its right of eminent domain will be used, if needed, to secure any remaining easements within the project installation period and that sufficient funds are available for paying for these easements, permits, or rights-of-way.

3. Court orders have been obtained from the Commissioners Court showing that county roads affected by structural works of improvement will either be closed, relocated, or raised two feet above emergency spillway crest elevation at no cost to the Federal Government, or permission granted to temporarily inundate the road, provided equal alternate routes can be provided.

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

5. Operation and maintenance agreements have been executed.

6. Public Law 566 funds are available.

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

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

PROVISIONS FOR OPERATIONS AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by the landowners and operators of the farms on which the measures are applied, under agreements with the McLennan County, Navarro-Hill, and Limestone-Falls 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 the management practices and maintenance needs. They will make district-owned equipment available for this purpose.

Structural Measures for Flood Prevention

The estimated annual operation and maintenance cost is $19,500, based on long-term price levels. The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 will be responsible for operation and maintenance of the 31 floodwater retarding structures and the 11.7 miles of channel improvement. The necessary maintenance work will be accomplished through the use of contributed labor and equipment, by contract, by force account, or a combination of these methods. The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 will establish a permanent reserve fund for this purpose in the following manner and amounts: As floodwater retarding structures are completed, $200 per year per structure will be placed in a reserve for operations and maintenance until the sum of $1,000 per structure for the first ten, $750 per structure for the next ten, and $500 per structure for the remaining 11 is established; and as channel improvement is completed, $200 per mile per year will be placed in the permanent reserve fund until the sum of $1,000 per mile for the first 10 miles and $1,500 for the remaining 1.7 miles is established. This will amount to $34,500 when all 31 floodwater retarding structures and the 11.7 miles of channel improvement are built. When it becomes necessary to use any of the reserve fund for maintenance expenditures, the district will take appropriate action to replenish the fund in the shortest feasible time.

All floodwater retarding structures and the channel improvement will be inspected at least annually and after each heavy rain or stream flow by representatives of the McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1. A Soil Conservation Service representative will participate in these inspections at least annually. For the floodwater retarding structures, items of inspection will include, but not be limited to the condition of the principal spillway and its appurtenances, the earth fill, the emergency spillway, the vegetative cover of the earth fill and the emergency spillway, and fences and gates installed as a part of the structure. For the improved channel items of inspection will include, but not limited to, the need for, (1) removal or control of woody vegetation, (2) removal of sediment bars, (3) control of meander, and (4) corrective measures to prevent gully erosion or head cutting inside drains.

The Soil Conservation Service, through the McLennan County and the Limestone-Falls 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 cosponsoring organizations and Federal representatives to inspect and provide maintenance for all structural measures and their appurtenances at any time.

The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 will maintain a record of all maintenance inspections made and all maintenance work done and have it available for inspection by the Soil Conservation Service.

The McLennan and Hill Counties Tehuacana Creek Water Control and Improvement District No. 1 fully understands its obligations for maintenance and will execute specific maintenance agreements prior to the issuance of invitation to bid on construction of the structural measures.

COST-SHARING

Public Law 566 funds are expected to provide technical assistance in the amount of $138,744 during the 8-year installation period to accelerate the installation of land treatment measures included in the plan for reduction of erosion and peak rates of runoff. These Public Law 566 funds will be in addition to $101,256 of Public Law 46 funds under going program criteria. Local interests will install these measures at an estimated cost of $1,429,578, which includes ACPS payments based on present program criteria (table 1).

The required local cost for structural measures consists of the value of land, easements, and rights-of-way, and the costs of administering contracts. These costs are estimated to be $828,702.

The entire cost of constructing structural measures, amounting to $3,058,663 will be borne by Public Law 566 funds. In addition, the installation services cost of $1,015,475 will be a Public Law 566 expense. This is a total Public Law 566 cost of $4,074,138 for the installation of structural measures.

The total project cost of $6,572,418 will be shared 64.1 percent $4,212,882 by Public Law 566 funds and 35.9 percent $2,359,536 by other than Public Law 566 funds. In addition, the cost of operation and maintenance ($19,500) annually will be borne by local interests.

CONFORMANCE OF PLAN TO FEDERAL LAWS AND REGULATIONS

The installation of the watershed protection and flood prevention project on the Tehuacana Creek watershed will make a substantial contribution to the objectives of the overall Brazos River development program.

This project conforms to all Federal laws and regulations and will have no known detrimental effects on any downstream projects which are now in existence or which might be constructed in the future.

SECTION 2

INVESTIGATIONS, ANALYSES, AND SUPPORTING TABLES

INVESTIGATIONS AND ANALYSES

Project Formulation

Project Objectives

Flood problems were discussed with the sponsoring local organizations and the following project objectives reached:

1. Determine, first, the needed land treatment measures, based on current needs, which remain to be applied in the watershed and which contribute directly to flood prevention.

2. Since it was apparent that land treatment measures alone would not attain the desired degree of flood protection, attempt to control the runoff from 60 percent of the watershed with floodwater retarding structures.

3. If releases from the principal spillways exceed existing channel capacities, provide additional capacity by clearing, snagging, or enlarging the present channel.

4. Provide additional flood protection, where economically feasible, with channel enlargement, floodways, levees, diversions, or a combination of these to uniformly reduce average annual flood damage at least 75 percent.

Land Treatment Measures

The status of land treatment measures for the Tehuacana Creek watershed was developed by Supervisors of the McLennan County, Navarro-Hill, and Limestone-Falls Soil Conservation Districts with assistance from personnel of the Soil Conservation Service work units at Waco, West, and Hubbard, Texas.

The measures needed and the practices effectively applied were considered for each farm or group of farms. This information was expanded to represent the needed land treatment measures to be applied. Estimates were made of the amounts of practices that will be applied during the 8-year installation period for the entire watershed (table 1). Trends in farming operation, amounts of land treatment practices already applied, soil conditions, grassland cover conditions, and other pertinent data were used in estimating these future land treatment needs. The cost of applying the land treatment measures was based on current costs and going program criteria.

Structural Measures

The procedures used to determine the most feasible plan of structural measures to meet the objectives of the sponsoring local organizations were as follows:

1. A base map of the watershed was prepared at a scale of 2 inches equals one mile showing watershed boundary, drainage pattern, system of roads and railroads, utility lines, and other pertinent information.

2. Using a copy of the base map, a current ownership map of all farms in the watershed was prepared by the Soil Conservation Service work units at Waco, West, Hubbard, and Groesbeck, Texas.

3. Photographic study supplemented by field examination indicated the limits of flood plain subject to flood damage.

4. Map and photo studies and field investigations indicated the watershed should be divided into three evaluation units, each with its own system of interdependent structural measures. These evaluation units are: (1) The mainstem of Tehuacana Creek, (2) Williams Creek, and (3) Tradinghouse Creek.

5. United States Department of the Interior Geological Survey 7.5 minute, advance proof, quadrangle sheets with 10-feet contour interval were used to locate all possible floodwater retarding structure sites. After a field examination and stereoscopic photo study of these sites was made, tentative storage tables were developed for each site. Sites which did not have sufficient storage capacities were dropped from further consideration.

6. From the 49 sites having sufficient storage capacities, 42 were recommended to the local sponsoring organizations for further consideration and detail survey. A list of landowners whose farms probably would be affected by the floodwater retarding structures was prepared for each site and submitted to the local sponsoring organization to facilitate their study of the structures recommended for further consideration and detail survey.

7. After agreement was reached with the local sponsoring organizations on location of floodwater retarding structure sites for further consideration and detail survey, topographic maps with 4-foot contour intervals and a scale of 8-inches equals one-mine were prepared for each site. These surveys provided the necessary information to determine if the required sediment and floodwater detention storage could be obtained and to make an estimate of all installation costs of each structure.

Criteria outlined in Soil Conservation Service, Washington Engineering Memorandum No. 27, and Texas State Manual Supplement 2404.2 were used to determine the sediment and floodwater detention storage requirements, structure classification, principal and emergency spillway design, and freeboard.

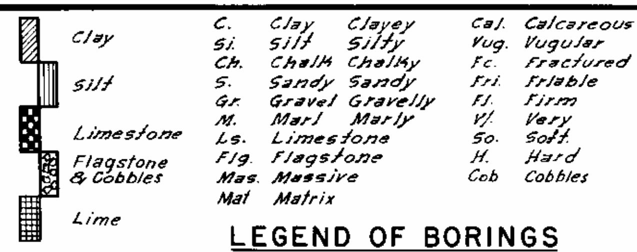
Sites which did not have sufficient storage capacities, or which would cause inundation of expensive improvements were dropped from further consideration. Sites 3, 3A, and 4 were placed in series to obtain the needed degree of control because sufficient detention storage could not be developed in site 4. Sites 16 and 17 were placed in series for the same reason and to provide flood protection for intervening flood plain lands.

8. Data obtained in land treatment need studies for the watershed, as well as hydraulic, hydrologic, geologic, sedimentation, and economic investigations provided the necessary means for evaluating various combinations and locations of floodwater retarding structures. As a result of this analysis it was determined that a system of 20 floodwater retarding structures on the mainstem of Tehuacana Creek, six structures on Williams Creek, and five structures on Tradinghouse Creek would be the most economical to install and would provide the degree of protection desired by the sponsoring organizations, except in Reaches C and D.

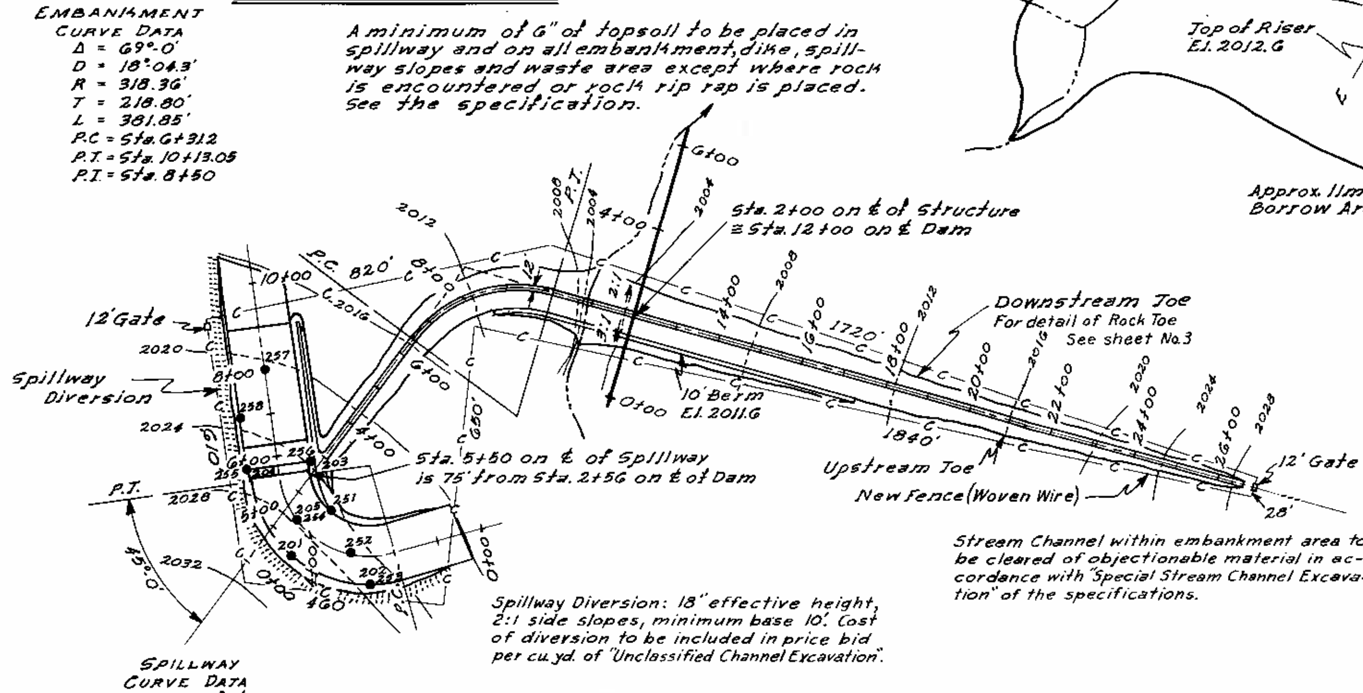
Plans of a floodwater retarding structure, typical of those planned for the watershed, are illustrated by figures 5 and 5A.

9. To attain the desired degree of protection, channel improvement was investigated in Reaches C and D. After consideration of such measures as levees, floodwater diversions and channel enlargement, it was determined that an enlarged channel, which could be constructed without alterations to existing highway and railroad bridges, would be the most feasible to install. This improvement would extend from the confluence of Tradinghouse and Tehuacana Creeks upstream to the present confluence of Tehuacana and Cottonwood Creeks, a distance of approximately 9.1 miles. Hydraulic investigations also revealed that the capacity of the existing channel from the confluence of Tradinghouse and Tehuacana Creeks downstream to the mouth of Tehuacana Creek, a distance of approximately 2.6 miles, could be increased sufficiently by removing all trees, brush, and stumps.

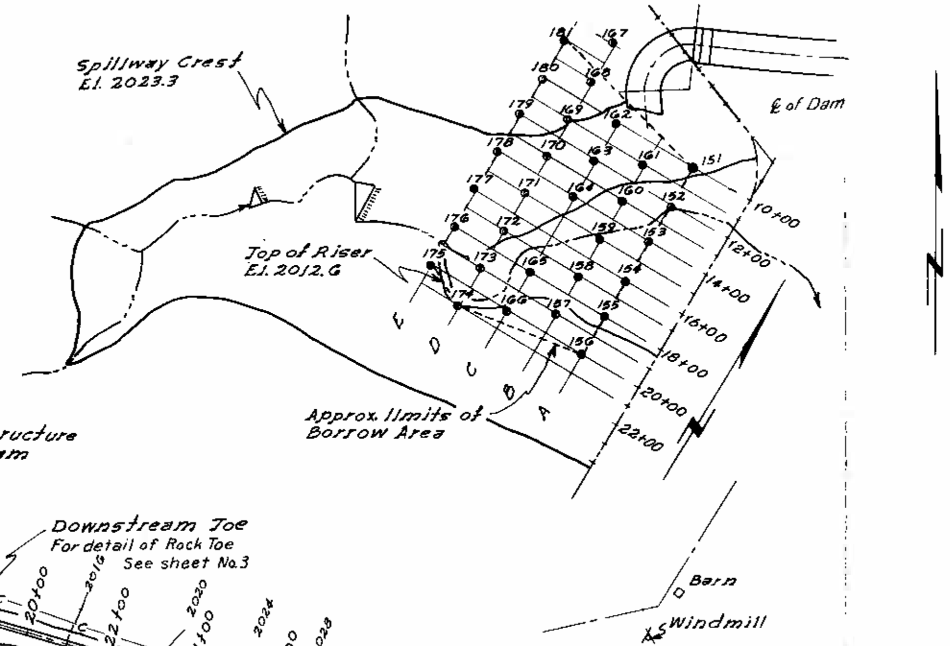
Additional cross section and profile data were obtained to supplement the available valley cross section data to make the channel improvement cost estimates.



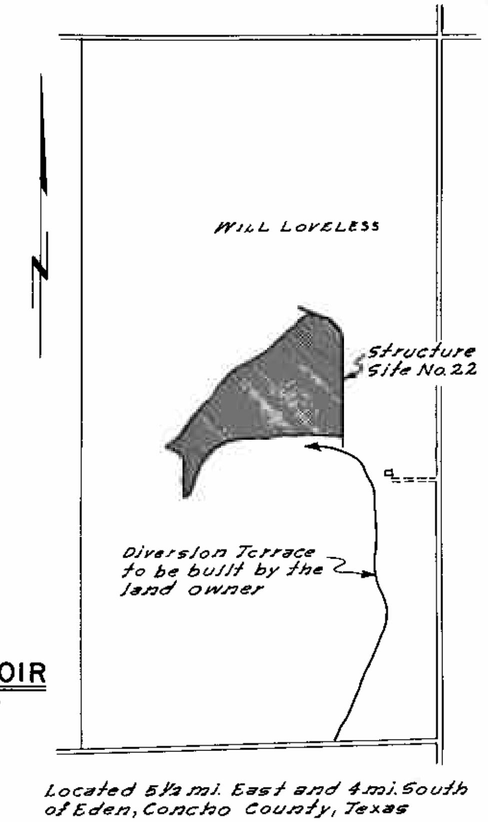
LEGEND OF BORINGS



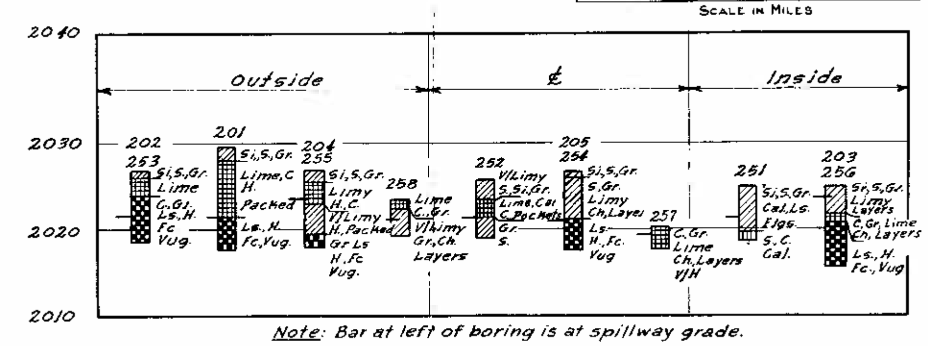
PLAN OF EMBANKMENT AND SPILLWAY



GENERAL PLAN OF RESERVOIR

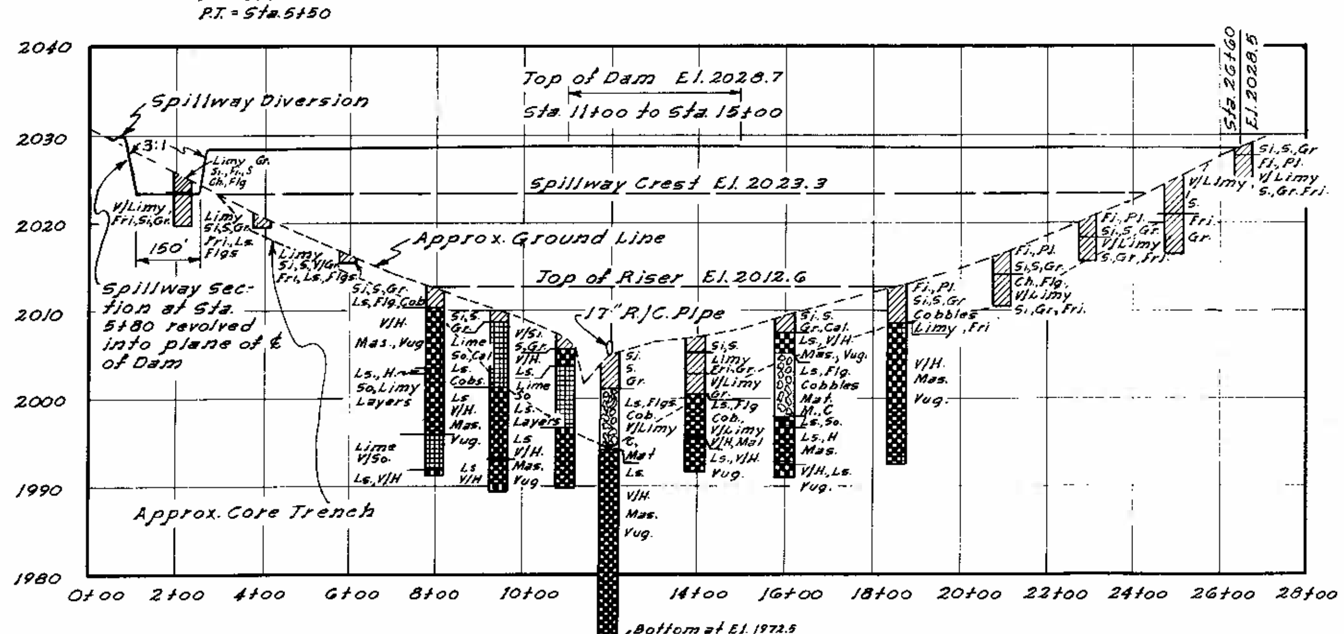


VICINITY MAP



LOG OF SPILLWAY BORINGS

SEE PLAN OF EMBANKMENT AND SPILLWAY



PROFILE ON ℄ OF DAM

Elevation	Surface Acres	Storage	
		Acre Ft.	Inches
2012.6	16.84	51.70	0.50
2016.0	30.76	132.66	1.28
2020.0	54.21	302.60	2.92
2023.3	74.94	515.68	5.00
2024.0	79.33	569.68	5.50
2028.0	108.17	944.68	9.13

Top of Dam (Effective) Elev.	2028.5
Spillway Crest Elev.	2023.3
Top of Riser Elev.	2012.6
Sediment Pool Elev.	2012.6
Drainage Area, Acres	1242.0
Sediment Storage, Ac. Ft.	51.7
Floodwater Storage, Ac. Ft.	464.0

Figure 5
TYPICAL
FLOOOWATER RETARDING STRUCTURE
PLAN AND PROFILE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

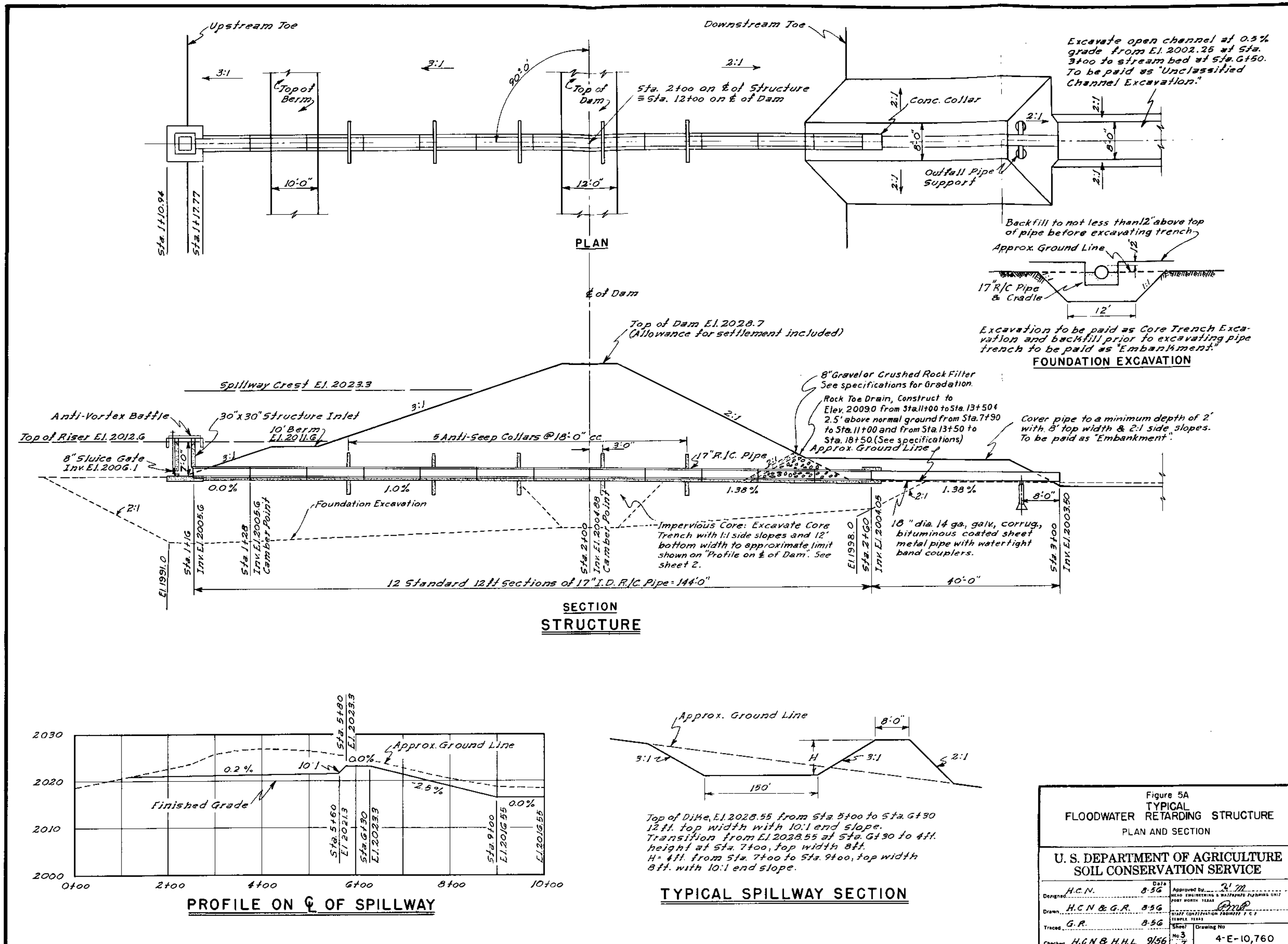
		Date
Designed	H.C.N.	8-56
Drawn	H.C.N. & G.R.	8-56
Traced	G.R.	8-56
Checked	H.C.N & H.H.L.	9/56

Approved by H.M.
HEAD ENGINEERING & WATERSHED PLANNING UNIT
FORT WORTH, TEXAS

BMB
STATE CONSERVATION ENGINEER, S.C.S.
TEMPLE, TEXAS

Sheet No 2 of 7

Drawing No 4-E-10,760


Upstream Toe
Downstream Toe
3:1
3:1
2:1
Top of Berm
Top of Dam
90°0'
Sta. 2+00 on ℄ of Structure = Sta. 12+00 on ℄ of Dam
Conc. Collar
Outfall Pipe Support
8'-0"
10'-0"
12'-0"
Sta. 1+10.94
Sta. 1+17.77
PLAN
Excavate open channel at 0.5% grade from El. 2002.25 at Sta. 3+00 to stream bed at Sta. 6+50. To be paid as "Unclassified Channel Excavation."
Backfill to not less than 12" above top of pipe before excavating trench
Approx. Ground Line
17" R/C Pipe & Cradle
12'
Excavation to be paid as Core Trench Excavation and backfill prior to excavating pipe trench to be paid as "Embankment."
FOUNDATION EXCAVATION
℄ of Dam
Top of Dam El. 2028.7 (Allowance for settlement included)
Spillway Crest El. 2023.3
Anti-Vortex Baffle
30"x30" Structure Inlet
10' Berm El. 2011.6
Top of Riser El. 2012.6
8" Sluice Gate Inv. El. 2006.1
5 Anti-Seep Collars @ 18'-0" cc
17" R/C Pipe
8" Gravel or Crushed Rock Filter See specifications for Gradation.
Rock Toe Drain, Construct to Elev. 2009.0 from Sta. 11+00 to Sta. 13+50 & 2.5' above normal ground from Sta. 7+90 to Sta. 11+00 and from Sta. 13+50 to Sta. 18+50 (See specifications)
Approx. Ground Line
Cover pipe to a minimum depth of 2' with 8' top width & 2:1 side slopes. To be paid as "Embankment".
0.0%
1.0%
1.38%
1.38%
Foundation Excavation
Impervious Core: Excavate Core Trench with 1:1 side slopes and 12' bottom width to approximate limit shown on "Profile on ℄ of Dam". See sheet 2.
18" dia. 14 ga. galv. corrug. bituminous coated sheet metal pipe with watertight band couplers.
El. 1991.0
Sta. 1+16
Inv. El. 2005.6
Sta. 1+28
Inv. El. 2005.6
Camber Point
Sta. 2+00
Inv. El. 2004.88
Camber Point
El. 1998.0
Sta. 2+60
Inv. El. 2004.05
Sta. 3+00
Inv. El. 2003.50
12 Standard 12 ft Sections of 17" I.D. R/C Pipe - 144'-0"
40'-0"
SECTION
STRUCTURE
2030
2020
2010
2000
0+00
2+00
4+00
6+00
8+00
10+00
Sta. 5+80 El. 2023.3
Approx. Ground Line
0.2%
10:1
0.0%
2.5%
0.0%
Finished Grade
Sta. 5+60 El. 2021.3
Sta. 6+30 El. 2023.3
Sta. 9+00 El. 2016.55
El. 2016.55
PROFILE ON ℄ OF SPILLWAY
Approx. Ground Line
8'-0"
3:1
H
3:1
2:1
150'
Top of Dike, El. 2028.55 from Sta. 5+00 to Sta. 6+30 12 ft. top width with 10:1 end slope. Transition from El. 2028.55 at Sta. 6+30 to 4 ft. height at Sta. 7+00, top width 8 ft. H = 4 ft. from Sta. 7+00 to Sta. 9+00, top width 8 ft. with 10:1 end slope.
TYPICAL SPILLWAY SECTION
Figure 5A
TYPICAL
FLOODWATER RETARDING STRUCTURE
PLAN AND SECTION
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed H.C.N. 8-56
Drawn H.C.N & G.R. 8-56
Traced G.R. 8-56
Checked H.C.N & H.H.L. 9/56
Sheet No. 3 of 7
Drawing No. 4-E-10,760

10. Evaluation of these proposed works of improvement on an incremental basis indicated that the additional benefits which could be obtained would be more than enough to justify the inclusion of this 11.7 miles of channel improvement.

11. Cost distribution (table 2) and structure data tables (table 3 and 3A) were prepared to show for each structure and type of structure, the estimated cost of the structure, the drainage area, the capacity needed for detention and for sediment storage in acre-feet and in inches of runoff from the drainage area, the release rate of the principal spillway, the acres inundated by the sediment and detention pools, the volume of fill in the dams, and other pertinent data.

12. It was determined that sufficient benefits would accrue in Tradinghouse, Williams, and Tehuacana Creek above its confluence with Williams Creek flood plains to set up three construction units. However, the sponsoring local organizations requested that the entire watershed be considered as one construction unit.

Hydrologic Investigations

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

1. Basic meteorologic and hydrologic data were tabulated from Climatological Bulletins, U. S. Weather Bureau, and Water Supply Papers, U. S. Geological Survey, and analyzed to determine average precipitation depth-duration relationships, seasonal distribution of precipitation, the historical flood series to be used in the evaluation of the program, rainfall-runoff relationship of geology, soils, and climate to runoff depth-frequency for single storm events.

2. Engineering surveys were made of channel and valley cross sections selected to represent adequately the stream hydraulics and flood plain area. Preliminary locations for cross sections were made by stereoscopic examination of aerial photographs of the flood plain. The final locations were selected on the ground, giving due consideration to the needs of the economist and the geologist. The evaluation reaches were delineated in conference with the economist and geologist.

3. The present hydrologic condition of the watershed was determined by surveying the soil-cover condition of a 22 percent sample of the watershed and expanding this data to the entire watershed. The future hydrologic condition of the watershed was determined by obtaining from the work unit conservationists the changes in land use and treatment that could be expected with an accelerated land treatment program during the installation period. Runoff

curve numbers were computed from the soil-cover complex data and used with figure 3.10 -1, National Engineering Handbook, Section 4, Supplement A, to determine the depth of runoff from individual storms in the historical storm series. Monthly soil moisture indices were used. Adjustments were made in the computed runoff curve numbers to make the computed average annual runoff compare favorably with the records from stream gages on similar watersheds in the area.

4. Cross section rating curves were computed from field survey data listed in item 2, above, by solving water surface profiles for various discharges, using Doubt's Method as described in pages 3.14-7 to 3.14-13 of the National Engineering Handbook, Section 4, Supplement A.

5. A variation of the concordant flow theory was used to determine the relationship of peak discharge and drainage area. High water marks from the storms of May 1, 1956 and May 2 and 3, 1958 were used to check the adequacy of equation 15 on page 3.16-4 of the National Engineering Handbook, Section 4, Supplement A. The time of concentration used in equation 15 was computed from the velocities obtained in developing the rating curves. Figure 3.15-3 was used in the upstream reaches where no valley cross sections were surveyed. Equation 15 provided a comparable method of determining these relationships under the conditions of improved channels.

6. Stage-area inundated curves were developed from field survey data for each portion of the valley represented by a cross section. Composite runoff-area inundation curves were developed for each evaluation reach by routing selected volumes of runoff downstream by concordant flow procedures and summating the area flooded for each portion of the valley represented by a cross section in the evaluation reach. Similarly a family of runoff-area inundation curves were developed to reflect the effect of the system of floodwater retarding structures and an improved channel.

7. The period 1923 to 1942, inclusive, was selected as the most representative of normal precipitation on the watershed, and is the period from which the historical evaluation flood series was developed. The evaluation flood series was limited to storms which did not exceed 25-year frequency.

8. Determinations were made of the area that would have been inundated by each storm in the evaluation series under each of the following conditions:

   a. The present conditions of the watershed remaining static.

   b. The installation of land treatment measures for watershed protection.

c. The installation of land treatment measures and floodwater retarding structures.

d. The installation of land treatment measures, floodwater retarding structures and an improved channel.

9. Runoff computations were made, giving due consideration to antecedent moisture conditions, for each runoff-producing 24-hour storm that occurred during the evaluation period. The Hazen method of analysis was used to develop a runoff frequency curve using the maximum annual storm runoff values. It indicates that flooding will occur each year in each evaluation reach.

10. The largest rain which occurred during the 20-year period was a storm of 9.39 inches on September 27 and 28, 1936.

If soil moisture condition II is assumed, the computed runoff from a storm of this size is 7.31 inches. The annual flood frequency line developed by means of the computed runoff for the 20-year period indicates a frequency of once in 100 years for the storm. The following table indicates the flows at which flood damages begin in the various evaluation reaches. The section referred to as the reference section is valley section number 27, which is near the downstream boundary of the watershed (figure 1).

Evaluation Reach (Figure 1)	Valley Cross Sections	Capacity of Smallest Section in Reach (c.f.s.)	Discharge at Reference Section (27) (c.f.s.)
A	Tr-1 thru Tr-10 X-1 thru X-3 Riggs 1 and Riggs 2	225	972
B	W-1 thru W-14	500	1,388
C	R-20 thru R-27	1,200	1,249
D	R-16 thru R-19 LT-1 thru LT-6	250	1,180
E	R-2 thru R-15 B-1 thru B-4 E-1 thru E-4 Ri-1 thru Ri-6 C-1 thru C-2 Wolf 3 and Wolf 4	295	763

11. The minimum floodwater detention volume in the structures as determined in accordance with Washington Engineering Memorandum No. 27, using Yarnell's 6-hour, 25 and 50-year frequency rainfall amounts, is 3.92 and 4.75 inches respectively. In accordance with Texas State Manual Supplement 2404.2, the recommended detention storage volume for this watershed varies from 6.10 inches for Class A structures to 8.0 inches for Class B structures depending on size of drainage area. The recommended detention storage volume for Class A and Class B structures less the volume which would be released through the principal spillway during a 2-day period was used as the minimum detention storage volume for all floodwater retarding structure sites except No. 8, 17, and 24. For economical reasons detention volumes less than recommended were used for these three sites; however, the volumes actually used are in excess of the minimum required by Washington Engineering Memo.No. 27. Detention volumes in excess of those recommended in accordance with Texas State Manual Supplement 2404.2 were used in a number of sites to obtain a more economical or desirable emergency spillway or structure design.

    Frequency of use of emergency spillways, based on regional analysis of gaged runoff from similar watersheds, was determined by adding to the actual detention storage the volume which would be released by the principal spillways during a 2-day period.

12. The capacity of the smallest channel section through which the release flows from the floodwater retarding structures would pass was used to determine the average capacities of the principal spillways. These average release rates range from 5 to 20 CSM. The higher rates were used in some structures to decrease the period of time highly productive land would be inundated or to insure less frequent use of emergency spillways for sites 8, 17, and 24.

13. The appropriate emergency spillway and freeboard design storms were selected from figures 3.21-1 and 3.21-4 of the National Engineering Handbook, Section 4, Supplement A, in accordance with criteria contained in Washington Engineering Memorandum No. 27, and Texas State Manual, Supplement 2404.2. After making area adjustment for point rainfall, as prescribed in the references above, the appropriate moisture condition II curve was used to determine the runoff. The following moisture condition II curves were used to determine runoff above the sites: Curve No. 78 for sites 20 and 29; curve No. 79 for sites 1, 1A, 2, 3, 3A, 4, 5, 7, 19, 21, 24, and 25; curve No. 80 for sites 8, 9, 10, 13, 14, 16, 17, 18, 22, 23, 26, and 27; curve No. 81 for sites 6, 11, 15, and 28; and curve No. 82 for site 12.

14. Spillway hydrographs were developed for each site in the watershed.

The principal spillway hydrographs represented a flood event that will not be exceeded, on the average, more often than once in 25 years for Class A structures (Sites 1, 1A, 2, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, and 29) or 50 years for Class B structures (Sites 3, 3A, 4, 6, 15, 23, and 24). For Class A structures the emergency spillway and freeboard hydrographs were computed using moisture condition II with 0.5 and 1.0, respectively, of the point rainfall of the 6-hour storm. Emergency spillway hydrographs and freeboard hydrographs for Class B structures were developed in the same manner except that .75 and 1.5 of the point rainfall, respectively, were used. Since use of the emergency spillway hydrographs resulted in either no flow or very shallow flow through emergency spillways, the dimensions of the emergency spillways were determined from the freeboard hydrographs. One foot of freeboard was provided above the maximum water elevation reached in routing the freeboard hydrograph. Hydrographs were developed for each of the floodwater retarding structures by the distribution graph method. The combination emergency spillway width and depth, and elevation of top of dam for the most economical structure was determined by an empirical equation. The final preliminary design was obtained on a representative number of sites (including all sites in series) by the Goodrich flood routing method described on page 5.8-12 of the National Engineering Handbook, Section 5.

15. The initial design of the improved channel was to carry approximately one inch of runoff from the uncontrolled area plus principal spillway releases from the floodwater retarding structures. The design slope was obtained through the average of the cross section elevations at which floodwater damage starts. This grade line was then used as the top of the designed channel. A small pilot channel was included as an aid in retarding the development of meanders. This portion of the channel has a uniform bottom width of 30 feet and a depth varying from 1.7 to 2.8 feet to maintain a velocity of approximately 2 feet per second on the changing slope. A roughness coefficient of .030 was used in all segments of the improved channel. The total depths were determined by limiting the velocity to 5 feet per second in the segment formed by the pilot channel. The widths of the overflow segments on each side of the pilot channel were then determined to provide the remainder of the required capacities. The greatest total bottom width was 171 feet in reach number R-19, with lesser widths of 137, 109, and 151 in R-20, R-21, and R-22 respectively. The final plan (table 3A) has a uniform bottom width of 170 feet from reach R-19 through reach R-22 and retains the slopes and depths of the initial design.

Sedimentation Investigations

Sediment Source Studies

Sediment source studies, to determine the 50-year sediment storage requirements, were made in the drainage areas of the 31 planned floodwater retarding structures according to the following procedures:

1. Detailed investigations were made in the drainage areas above 16 of the planned floodwater retarding structures. Estimates of sediment rates were made for the remaining 15 sites based on similarity of these sites to sites which had been surveyed in detail.

2. Field surveys included: mapping the soil unit by slope in percent, slope length in feet, present land use, present land treatment on cultivated land, present cover condition classes on pasture and woodland, land capability classes, lengths and widths of all gullies, lengths and widths of all streambank affected by erosion, estimated annual lateral erosion of gullies and streambanks in feet, and average depth of gullies and streambanks.

3. Office computations included summarizing the field data by sources (sheet erosion, gully erosion, and streambank erosion) in order to fit these data into formulas for computation of gross annual erosion in acre feet.

   The following formula was used for computing sheet erosion:

   $E = A \times F \times SF \times CF \times RF$, where
   E = Sheet erosion in acre feet per year
   A - Area in acres
   F - Basic erosion rate of soil unit in feet per year
   SF - Slope factor, based on percent and length of slope
   CF - Cover factor, based on present cover and land treatment
   RF - Rainfall factor based on maximum two-year 30-minute rainfall intensity

   The following formula was used for computing gully and streambank erosion:

   $E = N \times L \times P \times H \times LE \div 43{,}560$, where
   E - Erosion in acre feet per year
   N - Number of banks affected
   L - Length of gully or streambank in feet
   P - Percent of gully or streambank affected by erosion
   H - Average height of bank in feet
   LE - Estimated annual lateral erosion in feet.

4. Field surveys to determine the estimated sediment rates, under present conditions, consisted of mapping the land use, and arranging the sites to be estimated into homogeneous groups.

5. Office computations to determine the estimated sediment rates, under present conditions, consisted of preparation of sediment source summary sheets based on the homogeneous grouping of the sites and the detailed investigations.

6. The sediment rates were then adjusted to reflect the effect of expected land treatment in the drainage areas of the planned floodwater retarding structures. The computed sediment storage for each site is based on a gradual improvement of watershed conditions as a result of the installation of needed land treatment measures during the first 10 years and 40 years with these measures operating at 75 percent effectiveness.

7. The ratio of sediment storage volume in the reservoir to soil in place was estimated to be 1.4 for the watershed.

8. The allocation of sediment in the reservoir was 15 percent in the detention pool and 85 percent in the sediment pool.

Flood Plain Sedimentation and Scour

Sedimentation and scour damage investigations were made to evaluate the nature and extent of physical damage to flood plain land, giving due consideration to agronomic practices, soils, land treatment, crop yields, and land capabilities.

1. Borings with a power soil sampler, and hand auger were made along each of the valley cross sections, (figure 1) making note of the depth and texture of the deposit, soil condition, scour channels, sheet scour areas, stream channel degradation and/or aggradation, and other pertinent factors affecting flood plain damage.

2. The elevation of the original flood plain before modern deposition began was estimated for each valley section.

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

4. A damage table was developed to show percent damage by depth increment for deposition and percent damage by depth and width for scour.

5. The depth and width of the modern alluvial deposits and scour areas were measured and tabulated.

6. The damage areas were grouped by segments, which consisted of the area between two to five valley sections.

7. Within each of the segments the area for each depth increment of deposition and scour was computed.

8. The damage to the productive capacity of the flood plain was assessed by percent for each category of damage.

9. The sedimentation and scour damages were summarized by evaluation reaches for the entire flood plain and adjusted for recoverability of productive capacity. Estimates for recoverability of productive capacity were developed as a result of field studies and interviews with farmers.

10. Using the erosion rates as a basis, the average annual sediment yield at selected valley sections along the flood plain was computed for present conditions and with land treatment and structures installed. The results were compared to show the average reduction of overbank deposition in the watershed. The reduction of scour damage due to installation of the complete project is based on reduction of depth and area inundated.

Sediment and Erosion Damages

Since the sediment source studies indicated erosion rates in excess of two inches in the drainage areas above floodwater retarding structures sites 1 through 9, special studies were made above each of these sites to determine if additional erosion control measures were needed to reduce the high sediment production. Since more than 75 percent of the gross erosion above sites 1 through 9 results from sheet erosion, it was found that additional erosion control measures could not be economically justified.

The average rate of sediment deposited per square mile of drainage area is 1.87 acre-feet annually.

Using the detailed sediment source studies as a basis, it was found that approximately 93 percent of the gross erosion in the upland areas of the watershed results from sheet erosion and 7 percent from modern gully and streambank erosion. The proper application of the approximate 60 percent effective land treatment that can reasonably be expected to be installed will reduce sediment production from the upland areas approximately 31 percent.

Geologic Investigations

Preliminary geologic dam site investigations were made at each of the planned floodwater retarding structure sites. These studies included valley slopes, alluvium, channel banks, and exposed geologic formations. Borings with a hand auger were made at representative sites to determine the nature and extent of embankment material and emergency spillway excavation that might be encountered in construction.

Description of Problems

Formations of the Taylor and Austin Groups of the Upper Cretaceous Series outcrop in the watershed. Approximately 95 percent of the area is underlain by the Taylor Group, with the Austin Group out-cropping in the remaining 5 percent of the area near the northwestern boundary of the watershed.

The formations in the Taylor group include Taylor (undivided), Wolf City, and Durango. The Taylor (undivided) consists of marly clays, and shales containing chert gravel. All the planned floodwater retarding structure sites except those mentioned in the following paragraph are located within this outcrop. Foundation problems will be minor, except where gravel may be encountered in the alluvium and cause drainage problems. Scattered pockets of gypsum are known to occur. If encountered in borrow areas compaction may be difficult to obtain.

The Wolf City and Durango formations are irregular and disconnected outcrops scattered over the southern half of the watershed. The formations are similar in composition, consisting of sandy marls, with thin partings of clay and sandstone. Gypsum is present in small amounts in these formations and may make proper compaction difficult to obtain. Sites 6, 17, 18, 24, and 29 occur within the outcrop of the Wolf City and Durango formations. There should be few foundation problems at these sites.

Rock excavation is not anticipated at any site in the watershed. Soils for embankment purposes are in ample quantity and should provide good shear resistance, low permeability, and high density unless gypsum is encountered in large enough quantities. The soils, as classified by the Unified Soil Classification System, are generally CL, CH, and SC.

There are no sites located in the Austin group which consist of chalk and marly clays. The sharp fault contact between the Austin and Taylor Groups will not be encountered in construction.

The soils in the watershed are very susceptible to erosion when stripped of vegetative cover. Embankments and emergency spillways will be vegetated as soon as possible after construction. Maximum permissible velocities in the emergency spillways with good Bermudagrass cover will be 8 feet per second, as recommended in SCS Technical Paper 61.

Geologic investigations in the area of planned channel improvement revealed that no major problems will be encountered during construction. Maximum velocities and side slopes used in channel design were determined by using the recommendations in SCS Technical Paper 61.

Detailed investigations, including exploration with core-drilling equipment, will be made at all planned floodwater retarding structure sites prior to their construction. Laboratory tests will be made to determine the suitability and handling of the available embankment, cutoff wall, and foundation material.

Economic Investigations

Determination of Annual Benefits from Reduction in Damages

Agricultural damage estimates were based upon schedules obtained in the field, covering approximately 52 percent of the flood plain of Tehuacana Creek and its tributaries. These schedules covered land use, crop distribution under present conditions, crop yields and historical data on flooding and flood damage. Most of the flood damage information obtained was for floods which occurred in 1957 and 1958. Analysis of this information formed the basis for determining damage rates for various depths and seasons of flooding. In calculating crop and pasture damage, expenses saved, such as costs of harvesting, were deducted from the gross value of the damage. The proper rates of damage were applied flood by flood, to the floods covering the period 1923 through 1942 and an adjustment was made to take into account the effect of recurrent flooding when several floods occurred within one year. The flood plain land use was mapped in the field. Normal yields were based on data obtained from the schedules supplemented by information obtained from agricultural workers in the area.

It was found that significant differences in land use, yields, frequency of flooding, and degree of future use were sufficient to justify the division of the flood plain into five evaluation reaches. Each of these evaluation reaches has its own damageable value.

The evaluation reaches (figure 1) are:

Reach A - All of Tradinghouse Creek to its confluence with the mainstem of Tehuacana Creek.

Reach B - All of Williams Creek to its confluence with the mainstem of Tehuacana Creek.

Reach C - From the confluence of Tehuacana Creek with the Brazos River upstream to a point half-way between valley cross sections 19 and 20.

Reach D - From a point half-way between valley cross sections 19 and 20 upstream to a point half-way between valley cross sections 15 and 16, including Little Tehuacana Creek.

Reach E - From a point half-way between valley cross sections 15 and 16 upstream to a valley cross section 1, including Elm, Rice, Cottonwood, Wolf and Brookeen Creeks.

Floodwater, scour, and sediment damages, for each reach were calculated under present conditions and under conditions that will prevail after completion of each class of measures to be installed. The difference between average annual damages at the time of initiation of each class of measures and those expected after its installation constitutes the benefit brought about by that class of measures through reduction of damages. Benefits from reduction of crop and pasture damages and flood plain scour resulted from the combined effects of reduction in area inundated and reduced depth of inundation. Benefits from reduction of sediment damage, derived from each class of measures, were determined on the basis of estimated reduction in rate of sediment production and in area flooded after installation of each class of measure.

Estimates of damages to other agricultural property such as fences, livestock, farm equipment and levees were obtained from analysis of flood damage schedules and correlated with size of floods. Estimates of damages to roads and bridges in the flood plain were obtained from the McLennan County Engineer and from the State Highway Department maintenance foreman. These estimates were supplemented by information obtained from local farmers.

Indirect damages in this watershed primarily involve additional travel time for farmers, school bus transportation, and mail delivery; costs for extra feed for livestock during and following floods, and the like. Upon analysis, it appeared that these damages are about 10 percent of the direct damage.

Farmers in the flood plain were asked to state changes made in land use as a result of past flooding. This information, together with landowners' and operators' estimates of changes in land use and crop distribution as a result of reduction in flood extent and frequency, was the basis for estimating benefits from restoration of productivity. Benefits from restoration of productivity are included as crop and pasture benefits. Consideration was given to increased damage after restoration of productivity and the added damage was deducted. All benefits from restoration of productivity are net benefits remaining after production, harvesting, and all other allied costs were deducted. All benefits from restoration of productivity were discounted to provide for a 5-year lag in accomplishment. They totaled $55,089 annually at long-term price levels, ARS Projection of September 1957.

In some areas the reduction in flooding will be sufficiently great to permit profitable clearing of woods, not previously in cultivation, for conversion to pasture or crops. The net increased value of production from this source, after deducting all costs and discounting for a lag in accomplishment, was estimated to be $19,637 annually and is recorded as a benefit from changed land use in table 7.

A study was made of crops under acreage allotments, chiefly cotton in this watershed. For the purpose of economic evaluation it was assumed that the only change in cotton acreage that would result from the project would be a shift from lands involved in the structural sites to flood plain lands. Increases in the value of production on the flood plain from this source were classed as a benefit. Losses in the value of production in the structure sites were counted as a project cost in the manner described below. If there should be an increase in the total acreage of cotton as a result of the project, the benefits would be greater than those calculated.

Areas that will be inundated by the sediment and detention pools of floodwater retarding structures and areas involved in channel improvement were excluded from the damage calculations. An estimate was made, however, of the value of production lost in these areas after the installation of the program. 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 31 floodwater retarding structures and 11.7 miles of channel improvement were determined by individual appraisal in conjunction with representatives of the sponsoring organizations. Floodwater retarding structure site costs were based on full land value for the sediment pools, 75 percent of the value of cultivated land in detention pools and one-half value of pasture and woods in detention pools, since the land in detention pools will be used as pasture. Since some of the land involved in the detention pools of sites is intensively cultivated, it was felt the 75 percent of the land value more accurately reflected the loss in these areas than the 50 percent ordinarily used. The average annual net loss in production within the sites and land needed for channel improvement was calculated and this value was compared with the amortized cost of the land required for the floodwater retarding structures and channel improvement. The larger amount was used in the economic appraisal of the program to insure a conservative appraisal.

Determination of Annual Benefits Outside Watershed Resulting from Project

Data from the Corps of Engineers report on the survey of the Brazos River and tributaries was analyzed and damage to the flood plain of the Brazos River from Tehuacana Creek downstream to river mile 317.9, with all of the proposed C of E' structures constructed, was calculated. Benefits from the reduction of these remaining damages were apportioned back to the floodwater retarding structures in proportion to the reduction in flooding resulting from them. All benefits were calculated at long-term prices.

Details of Methodology

Details of the procedure used in the investigations are described in the Soil Conservation Service Interim Economics Guide for Watershed Protection and Flood Prevention, Revised April 1, 1956.

Fish and Wildlife Investigations

The following is the summary of the report of a reconnaissance study made by the Fish and Wildlife Service, USDI, dated June 7, 1957.

> "Our reconnaissance study of the proposed project for Tehuacana Creek watershed indicates that fish and wildlife resources generally will be either benefited or not significantly affected by the watershed protection measures contemplated. Several landowners have expressed an interest in measures for improving wildlife habitat. In line with this interest we would like to point out that floodwater retarding structures which will have permanent pools and farm ponds that are expected to provide permanent aquatic habitat will provide benefits for wildlife and could yield a significant harvest of fish. To obtain maximum fish and wildlife benefits the reservoirs and ponds should be fenced to exclude livestock, and plants useful to wildlife should be established within the enclosures. If water is required for livestock, it should be piped to a tank outside the enclosure.
>
> It is recommended -
>
> (1) That impoundment areas and farm ponds be fenced to exclude livestock.
>
> (2) That, if water is required for livestock, the impoundment and ponds be designed to provide a tank outside the recommended enclosure to which water may be piped.
>
> Other than the above, there are no particular measures that should be incorporated in project work plans that would benefit fish and wildlife resources substantially, and no special measures to prevent damage to these resources are required. This office, working in cooperation with the Texas Game and Fish Commission, will be pleased to provide general advice on fish and wildlife management techniques which might be incorporated in project work plans and which would aid in maintaining fish and wildlife resources in the watershed for recreational use.
>
> No detailed studies by this Service, as provided for in Sections 5 and 6 of the May 12, 1955 Memorandum of Understanding, are deemed to be necessary."

TABLE 2 - ESTIMATED STRUCTURE COST DISTRIBUTION

Tehuacana Creek Watershed, Texas
Price Base: Current Price Levels

Structure Site Number	Public Law 566 Installation Cost					Other Installation Cost			Estimated Total Cost
	Construction		Installation Services						
	Engineers Estimate	Contingencies	Engineering	Other	Total Public Law 566	Adm. of Contracts	Easements & R/W	Total Other	
	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Floodwater Retarding Structures									
1	38,047	3,805	8,370	5,524	55,746	500	15,544	16,044	71,790
1-A	48,470	4,847	10,663	7,038	71,018	500	28,540	29,040	100,058
2	88,064	8,806	19,374	12,787	129,031	500	15,475	15,975	145,006
3	34,931	3,493	7,685	5,072	51,181	500	14,525	15,025	66,206
3-A	37,230	3,723	8,191	5,406	54,550	500	25,725	26,225	80,775
4	64,320	6,432	14,150	9,339	94,241	500	48,220	48,720	142,961
5	113,156	11,316	24,894	16,430	165,796	500	57,051	57,551	223,347
6	95,472	9,547	21,004	13,862	139,885	500	23,950	24,450	164,335
7	107,872	10,787	23,732	15,663	158,054	500	33,236	33,736	191,790
8	54,668	5,467	12,027	7,938	80,100	500	18,622	19,122	99,222
9	104,820	10,482	23,060	15,220	153,582	500	49,495	49,995	203,577
10	46,363	4,636	10,200	6,732	67,931	500	29,150	29,650	97,581
11	62,096	6,210	13,661	9,016	90,983	500	18,000	18,500	109,483
12	72,890	7,289	16,036	10,584	106,799	500	20,827	21,327	128,126
13	99,666	9,967	21,927	14,472	146,032	500	43,722	44,222	190,254
14	43,123	4,312	9,487	6,261	63,183	500	14,090	14,590	77,773
15	95,458	9,546	21,001	13,861	139,866	500	82,217	82,717	222,583
16	34,380	3,438	7,564	4,992	50,374	500	4,225	4,725	55,099

TABLE 2 - ESTIMATED STRUCTURE COST DISTRIBUTION - Continued

Tehuacana Creek Watershed, Texas
Price Base: Current Price Levels

Structure Site Number	Public Law 566 Installation Cost: Construction: Engineers Estimate (dollars)	Construction: Contingencies (dollars)	Installation Services: Engineering (dollars)	Installation Services: Other (dollars)	Total Public Law 566 (dollars)	Other Installation Cost: Adm. of Contracts (dollars)	Easements & R/W (dollars)	Total (dollars)	Estimated Total Cost (dollars)
Floodwater Retarding Structures									
17	76,943	7,694	16,927	11,172	112,736	500	22,600	23,100	135,836
18	47,227	4,723	10,390	6,857	69,197	500	12,821	13,321	82,518
19	122,600	12,260	26,972	17,802	179,634	500	38,426	38,926	218,560
20	46,163	4,616	10,156	6,703	67,638	500	6,337	6,837	74,475
21	113,143	11,314	24,891	16,428	165,776	500	25,887	26,387	192,163
22	29,640	2,964	6,521	4,304	43,429	500	11,725	12,225	55,654
23	19,157	1,916	4,215	2,782	28,070	500	4,650	5,150	33,220
24	115,270	11,527	25,359	16,737	168,893	500	17,602	18,102	186,995
25	87,756	8,776	19,306	12,742	128,580	500	25,370	25,870	154,450
26	43,677	4,368	9,609	6,342	63,996	500	7,043	7,543	71,539
27	24,400	2,440	5,368	3,543	35,751	500	5,550	6,050	41,801
28	68,190	6,819	15,002	9,901	99,912	500	21,077	21,577	121,489
29	53,700	5,370	11,814	7,797	78,681	500	12,600	13,100	91,781
Channel Improvement	691,710	69,171	152,176	100,436	1,013,493	500	58,400	58,900	1,072,393
GRAND TOTAL	2,780,602	278,061	611,732	403,743	4,074,138	16,000	812,702	828,702	4,902,840

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES

Tehuacana Creek Watershed, Texas

Item	Unit	STRUCTURE NUMBER 1	1-A	2	3	3-A	4	5
Drainage Area	sq.mi.	1.53	3.13	3.30	1.78	2.75	1/ 4.44	14.72
Storage Capacity								
Sediment	ac.ft.	200	200	199	199	199	199	196
Sediment reserve below riser	ac.ft.	85	334	365	28	181	487	1,374
Sediment in detention pool	ac.ft.	32	66	70	28	44	95	236
Floodwater detention pool	ac.ft.	504	1,064	1,057	774	1,100	1,918	4,712
Total	ac.ft.	821	1,664	1,691	1,029	1,524	2,699	6,518
Surface Area								
Sediment pool (top of riser)	acre	49	90	89	65	101	123	211
Floodwater detention pool	acre	97	207	198	167	221	280	581
Maximum Height of Dam	foot	30	36	28	22	29	34	40
Volume of Fill	cu.yd.	93,200	119,100	213,200	86,300	90,000	182,900	270,800
Emergency Spillway								
Type	-	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.
Frequency of use 2/	year	30	35	30	70	55	70	30
Design storm (emergency spillway hydrograph)								
Duration	hour	6	6	6	6	6	6	6
Rainfall 3/	inch	6.94	6.75	6.74	10.36	10.19	9.55	6.14
Runoff	inch	4.53	4.35	4.35	7.73	7.57	6.97	3.81
Bottom width	foot	70	100	130	90	240	340	290
Design depth	foot	0	0	0	0.4	0.6	0.5	0
Design capacity	c.f.s.	0	0	0	63	264	306	0
Freeboard 4/	foot	4.0	4.0	4.0	3.6	3.3	4.4	4.5
Total capacity	c.f.s.	1,435	1,270	2,780	1,926	4,704	9,200	7,105
Principal Spillway Capacity(Maximum)	c.f.s.	12	24	25	22	34	115	110
Capacity Equivalents								
Sediment volume, 200 ac-ft.Level	inch	2.46	1.20	1.13	2.10	1.36	0.84	0.25
Sediment reserve volume	inch	1.04	2.00	2.07	0.30	1.24	2.06	1.75
Sediment volume in detention pool	inch	0.40	0.40	0.40	0.30	0.30	0.40	0.30
Detention volume	inch	6.20	6.38	6.00	8.15	7.50	8.10	6.00
Spillway storage	inch	5.60	5.32	5.30	8.55	6.30	6.70	3.75
Class of Structure	-	A	A	A	B	B	B	A

Footnotes on last page.

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Tehuacana Creek Watershed, Texas

Item	Unit	STRUCTURE NUMBER 6	7	8	9	10	11	12
Drainage Area	sq.mi.	6.84	12.09	3.11	14.05	3.65	4.27	5.93
Storage Capacity								
Sediment	ac.ft.	197	200	199	195	200	200	199
Sediment reserve below riser	ac.ft.	606	961	100	1,304	92	113	244
Sediment in detention pool	ac.ft.	109	129	33	150	39	46	63
Floodwater detention pool	ac.ft.	2,846	3,740	680	4,534	1,168	1,401	1,939
Total	ac.ft.	3,758	5,030	1,012	6,183	1,499	1,760	2,445
Surface Area								
Sediment pool (top of riser)	acre	127	186	43	190	55	55	70
Floodwater detention pool	acre	326	478	106	484	154	162	210
Maximum Height of Dam	foot	34	31	27	35	28	34	34
Volume of Fill	cu.yd.	200,500	247,600	124,400	252,000	112,900	147,800	182,000
Emergency Spillway								
Type	-	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.
Frequency of use 2/	year	60	30	20	35	30	30	35
Design storm (emergency spillway hydrograph)								
Duration	hour	6	6	6	6	6	6	6
Rainfall 3/	inch	9.74	6.23	6.75	6.15	6.71	6.66	6.55
Runoff	inch	7.39	3.89	4.47	3.92	4.43	4.49	4.50
Bottom width	foot	470	330	200	290	200	110	160
Design depth	foot	1.1	0	0.4	0	0	0	0
Design capacity	c.f.s.	1,222	0	120	0	0	0	0
Freeboard 4/	foot	3.9	4.5	3.6	4.0	4.0	5.0	5.0
Total capacity	c.f.s.	14,340	8,510	4,280	6,200	4,280	3,350	4,880
Principal Spillway								
Capacity (Maximum)	c.f.s.	52	90	80	175	30	35	45
Capacity Equivalents								
Sediment volume, 200 Ac.-Ft. Level	inch	0.54	0.31	1.20	0.26	1.03	0.88	0.63
Sediment reserve volume	inch	1.66	1.49	0.60	1.74	0.47	0.52	0.77
Sediment volume in detention pool	inch	0.30	0.20	0.20	0.20	0.20	0.20	0.20
Detention volume	inch	7.80	5.80	4.10	6.05	6.00	6.15	6.13
Spillway storage	inch	4.70	3.90	3.01	2.75	3.75	4.23	3.96
Class of Structure	-	B	A	A	A	A	A	A

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Tehuacana Creek Watershed, Texas

Item	Unit	STRUCTURE NUMBER 13	14	15	16	17	18	19
Drainage Area	sq.mi.	11.60	2.91	5.75	1.46	1/13.45	2.40	14.85
Storage Capacity								
Sediment	ac.ft.	198	171	199	85	200	141	198
Sediment reserve below riser	ac.ft.	606	0	138	0	302	0	832
Sediment in detention pool	ac.ft.	124	15	31	8	72	13	158
Floodwater detention pool	ac.ft.	3,712	950	2,131	489	3,070	819	4,792
Total	ac.ft.	4,640	1,136	2,499	582	3,644	973	5,980
Surface Area								
Sediment pool (top of riser)	acre	139	32	62	19	89	28	218
Floodwater detention pool	acre	397	105	300	63	305	117	659
Maximum Height of Dam	foot	36	35	35	32	42	31	35
Volume of Fill	cu.yd.	232,800	106,900	228,400	81,000	182,900	117,100	258,100
Emergency Spillway								
Type	-	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.
Frequency of use 2/	year	30	30	65	30	20	35	35
Design storm (emergency spillway hydrograph)								
Duration	hour	6	6	6	6	6	6	6
Rainfall 3/	inch	6.26	6.77	9.85	6.95	6.14	6.82	6.14
Runoff	inch	4.01	4.49	7.50	4.65	3.91	4.53	3.81
Bottom width	foot	370	190	260	100	500	100	330
Design depth	foot	0	0	0.4	0.3	0	0	0
Design capacity	c.f.s.	0	0	182	50	0	0	0
Freeboard 4/	foot	4.5	4.0	4.6	3.8	4.8	4.0	4.0
Total capacity	c.f.s	9,060	4,070	7,540	2,230	13,600	2,100	6,700
Principal Spillway Capacity (Maximum)	c.f.s.	90	22	145	10	210	20	150
Capacity Equivalents								
Sediment volume, 200 Ac.-Ft. Level	inch	0.32	1.10	0.65	1.10	0.28	1.10	0.25
Sediment reserve volume	inch	0.98	0.00	0.45	0.00	0.42	0.00	1.05
Sediment volume in detention pool	inch	0.20	0.10	0.10	0.10	0.10	0.10	0.20
Detention volume	inch	6.00	6.12	6.95	6.30	4.28	6.40	6.05
Spillway storage	inch	3.36	3.18	6.60	3.90	2.42	4.70	3.80
Class of Structure	-	A	A	B	A	A	A	A

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Tehuacana Creek Watershed, Texas

Item	Unit	STRUCTURE NUMBER 20	21	22	23	24	25	26
Drainage Area	sq.mi.	1.82	8.06	1.95	0.80	4.75	9.84	2.58
Storage Capacity								
Sediment	ac.ft.	126	198	135	68	200	200	151
Sediment reserve below riser	ac.ft.	0	275	0	0	78	378	0
Sediment in detention pool	ac.ft.	19	86	21	9	25	52	14
Floodwater detention pool	ac.ft.	583	2,514	638	354	1,492	3,018	832
Total	ac.ft.	728	3,073	794	431	1,795	3,648	997
Surface Area								
Sediment pool (top of riser)	acre	32	108	28	17	77	111	35
Floodwater detention pool	acre	118	305	100	61	258	358	104
Maximum Height of Dam	foot	24	31	25	23	24	29	27
Volume of Fill	cu.yd.	105,000	274,200	61,600	46,100	71,000	206,700	96,100
Emergency Spillway								
Type	-	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.	Veg.
Frequency of use 2/	year	30	30	30	60	30	30	30
Design storm (emergency spillway hydrograph)								
Duration	hour	6	6	6	6	6	6	6
Rainfall 3/	inch	6.89	6.43	6.88	10.59	9.94	6.32	6.77
Runoff	inch	4.38	4.07	4.58	8.09	7.34	3.79	4.48
Bottom width	foot	250	320	300	140	370	210	230
Design depth	foot	0.2	0	0.2	0.8	0.9	0	0
Design capacity	c.f.s.	60	0	75	240	740	0	0
Freeboard 4/	foot	2.8	4.0	2.8	3.2	4.1	4.5	3.5
Total capacity	c.f.s.	3,300	6,800	4,000	3,000	11,300	5,400	4,000
Principal Spillway								
Capacity (Maximum)	c.f.s.	10	80	15	5	50	100	25
Capacity Equivalents								
Sediment volume, 200 Ac.-Ft. Level	inch	1.30	0.46	1.30	1.60	0.79	0.38	1.10
Sediment reserve volume	inch	0	0.64	0	0	0.31	0.72	0
Sediment volume in detention pool	inch	0.20	0.20	0.20	0.20	0.10	0.10	0.10
Detention volume	inch	6.00	5.85	6.13	8.30	5.90	5.75	6.05
Spillway storage	inch	4.38	3.83	3.42	6.90	6.50	3.80	3.00
Class of Structure	-	A	A	A	B	B	A	A

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Tehuacana Creek Watershed, Texas

Item	Unit	STRUCTURE NUMBER 27	28	29	Total
Drainage Area	sq.mi.	2.14	6.13	5.90	177.98
Storage Capacity					
Sediment	ac.ft.	5/ 1,377	200	199	6,828
Sediment reserve below riser	ac.ft.	0	324	22	9,229
Sediment in detention pool	ac.ft.	23	65	31	1,906
Floodwater detention pool	ac.ft.	631	1,963	1,918	57,343
Total	ac.ft.	2,031	2,552	2,170	75,306
Surface Area					
Sediment pool (top of riser)	acre	107	95	51	2,702
Floodwater detention pool	acre	154	252	200	7,527
Maximum Height of Dam	foot	40	30	29	xxx
Volume of Fill	cu.yd.	42,800	147,900	128,900	4,710,200
Emergency Spillway					
Type	-	R.C.Pipe 6/	Veg.	Veg.	xxx
Frequency of use 2/	year	25	35	35	xxx
Design storm (emergency spillway hydrograph)					
Duration	hour	6	6	6	xxx
Rainfall 3/	inch	6.86	6.53	6.55	xxx
Runoff	inch	4.56	4.37	4.08	xxx
Bottom width	foot	10' Diam. 6/	270	240	xxx
Design depth	foot	0	0	0	xxx
Design capacity	c.f.s.	0	0	0	xxx
Freeboard 4/	foot	4.5	4.0	4.0	xxx
Total capacity	c.f.s.	1,170	5,800	5,100	xxx
Principal Spillway					
Capacity (Maximum)	c.f.s.	20	60	60	xxx
Capacity Equivalents					
Sediment volume, 200 Ac.-Ft. Level	inch	5/ 12.10	0.61	0.63	xxx
Sediment reserve volume	inch	0	0.99	0.07	xxx
Sediment volume in detention pool	inch	0.20	0.20	0.10	xxx
Detention volume	inch	5.53	6.00	6.10	xxx
Spillway storage	inch	7.10	3.40	3.35	xxx
Class of Structure	-	A	A	A	xxx

Footnotes on next page

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURE - Continued

Tehuacana Creek Watershed, Texas

1/ Excluding the area from which runoff is controlled by other structures.

2/ Based on regional analysis of gaged runoff from 2-day storm. All frequencies of use will exceed the minimum 6-hour 25 or 50-year frequency volume set forth in Washington Engineering Memo. 27.

3/ For Class A structures 0.5 x P of the 6-hour rainfall shown by figure 3.21-1, NEH-4, Supplement A, and 0.75 x P for Class B structures.

4/ Difference in elevation between H_p of freeboard hydrograph and H_p of emergency spillway hydrograph plus 1.0 foot.

5/ Portion of existing storage that will be left for Mart standby municipal water supply, of which 319 acre-feet has been allocated for future sediment storage.

6/ Existing spillway, supplement by vegetative spillway, 30 foot bottom width crest 1.5 feet below top of dam. Depth of flow from freeboard hydrograph 0.3 foot.

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TABLE 3A - STRUCTURE DATA

CHANNELS

Tehuacana Creek Watershed, Texas

Channel Designation	Station Numbering for Reach		Watershed Area	Planned Channel Capacity	Bottom Width	Side Slope	Depth	Fall	Velocity at Design Depth	Volume of Excavation
	Station (100 ft.)	Station (100 ft.)	(sq.mi.)	(cfs/sq.mi.)	(ft.)	(h:v)	(ft.)	(ft./ft.)	(ft./sec.)	(cu.yd.)
R-16	1,338 + 16	1,404 + 80	142.80	2,525	120	1.5:1	6.0	.001	5	230,866
R-17	1,404 + 80	1,461 + 50	170.49	2,945	150	1.5:1	6.1	.001	5	225,930
R-18	1,461 + 50	1,517 + 03	177.46	3,196	166	1.5:1	6.1	.001	5	231,980
R-19	1,517 + 03	1,580 + 86	179.96	3,260	170	1.5:1	6.1	.001	5	289,529
R-20	1,580 + 86	1,655 + 26	182.34	3,985	170	1.5:1	7.2	.0008	5	308,169
R-21	1,655 + 26	1,723 + 71	247.46	5,267	170	1.5:1	9.0	.0006	5	290,370
R-22	1,723 + 71	1,816 + 80	251.62	5,133	170	1.5:1	9.1	.0006	5	448,847
Total										2,025,691

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TABLE 4 - SUMMARY OF PHYSICAL DATA

Tehuacana Creek Watershed, Texas

Item	Unit	Quantity Without Project	Quantity With Project
Watershed Area	sq.mi.	307.00	xxx
Watershed Area	acre	196,480	xxx
Area of Federally-Owned Land	acre	1,852	1,852
Area of Cropland	acre	112,301	112,007
Area of Grassland	acre	69,996	69,763
Area of Woodland	acre	9,620	7,552
Miscellaneous Area	acre	2,711	5,306
Overflow Area Subject to Damage	acre	1/ 17,390	1/ 12,855
Area Damaged By:			
Overbank Deposition	acre	2/ 10,009	3/ 1,961
Flood Plain Scour	acre	2/ 3,305	3/ 364
Annual Rate of Erosion			
Sheet	ac.ft.	1,048.49	712.97
Gully	ac.ft.	50.33	36.35
Streambank	ac.ft.	30.76	30.76
Scour	ac.ft.	242.99	26.10
Average Annual Rainfall	inch	35.0	xxx

1/ Area inundated by the runoff from 25-year frequency storm, based on gage records.

2/ Acreage on which some production loss occurs each year.

3/ The acreage on which production loss will occur each year after all recovery has taken place. Applies to all flooding up to the area inundated by the largest storm in the 20-year series.

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TABLE 5 - SUMMARY OF PLAN DATA

Tehuacana Creek Watershed, Texas

Item	Unit	Quantity
Years to complete project	year	8
Total installation cost		
Public Law 566 funds	dollar	4,212,882
Other	dollar	2,359,536
Annual O and M Cost		
Public Law 566 funds	dollar	0
Other	dollar	19,500
Average annual monetary benefits 1/	dollar	323,067
Agricultural	percent	91.5
Nonagricultural	percent	8.5
Structural Measures		
Floodwater retarding structures	each	31
Channel improvement	mile	11.7
Area Inundated by structures		
Flood plain		
Sediment pool	acre	1,173
Detention pool	acre	789
Upland		
Sediment pool	acre	1,529
Detention pool	acre	4,036
Watershed area above structures	acre	113,907
Reduction of floodwater damage	dollar	259,973
By land treatment measures		
Watershed protection	percent	8
By structural measures	percent	80
Reduction of sediment damage	dollar	45,826
By land treatment measures		
Watershed protection	percent	31
By structural measures	percent	49
Reduction of erosion damage	dollar	10,006
By land treatment measures		
Watershed protection	percent	12
By structural measures	percent	77
Flood prevention benefit from changed land use	dollar	19,637
Benefits outside of watershed	dollar	2,609

1/ From structural measures.

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TABLE 6 - ANNUAL COST

Tehuacana Creek Watershed, Texas

Measures	Amortization of Installation Cost 1/	Operation and Maintenance Costs 2/			Total
		Public Law 566	Other	Total	
	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Floodwater Retarding Structures 1 through 18 in combination with channel improvement	129,070	0	16,880	16,880	145,950
Floodwater Retarding Structures 19 through 24	26,833	0	1,498	1,498	28,331
Floodwater Retarding Structures 25 through 29	16,961	0	1,122	1,122	18,083
Total	172,864	0	19,500	19,500	192,364

1/ Price Base: 1958 prices amortized for 50 years at 2.5 percent.

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

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TABLE 7 - MONETARY BENEFITS FROM STRUCTURAL MEASURES

Tehuacana Creek Watershed, Texas
Price Base: Long-Term 1/

Item	Estimated Average Annual Damage: Without Project	After Land Treatment For W/S Protection	With Project	Average Annual Monetary Benefits
	(dollars)	(dollars)	(dollars)	(dollars)
Floodwater Damage				
Crop and Pasture	239,766	222,739	30,797	191,942
Other Agricultural	20,796	18,220	887	17,333
Nonagricultural (Road & Bridge)	34,333	30,670	3,238	27,432
Subtotal	294,895	271,629	34,922	236,707
Sediment Damage				
Overbank Deposition	57,270	39,516	11,444	28,072
Subtotal	57,270	39,516	11,444	28,072
Erosion Damage				
Flood Plain Scour	11,253	9,941	1,247	8,694
Subtotal	11,253	9,941	1,247	8,694
Indirect Damage	36,342	32,109	4,761	27,348
Total, All Damages	399,760	353,195	52,374	300,821
Changed Land Use to Crop Production	xxx	xxx	xxx	19,637
Benefits Outside Project Area 2/	xxx	xxx	xxx	2,609
TOTAL FLOOD PREVENTION BENEFITS	xxx	xxx	xxx	323,067
TOTAL PRIMARY BENEFITS	xxx	xxx	xxx	323,067
TOTAL MONETARY BENEFITS	xxx	xxx	xxx	323,067

1/ As projected by ARS, September 1957.

2/ Damage reduction on Brazos River flood plain below Tehuacana Creek.

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TABLE 8 - BENEFIT COST ANALYSIS

Tehuacana Creek Watershed, Texas

Measures	AVERAGE ANNUAL BENEFITS 1/ — Flood Prevention: Flood-water (dollars)	Sediment (dollars)	Erosion (dollars)	Indirect (dollars)	Other 2/ (dollars)	Total (dollars)	Average Annual Cost 3/ (dollars)	Benefit-Cost Ratio
Structural Measures for Flood Prevention								
Floodwater Retarding Structures 1 through 18 in combination with channel improvement	182,218	22,211	6,651	21,113	9,954	242,147	145,950	1.7:1
Floodwater Retarding Structures 19 through 24	32,108	3,120	1,252	3,644	10,914	51,038	28,331	1.8:1
Floodwater Retarding Structures 25 through 29	22,381	2,741	791	2,591	1,378	29,882	18,083	1.6:1
GRAND TOTAL	236,707	28,072	8,694	27,348	22,246	323,067	192,364	1.7:1

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

2/ Includes benefit to Brazos River flood plain and changed land use benefits.

3/ Derived from installation costs based on 1958 price level and operation and maintenance cost based on long-term price levels, as projected by ARS, September 1957.

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