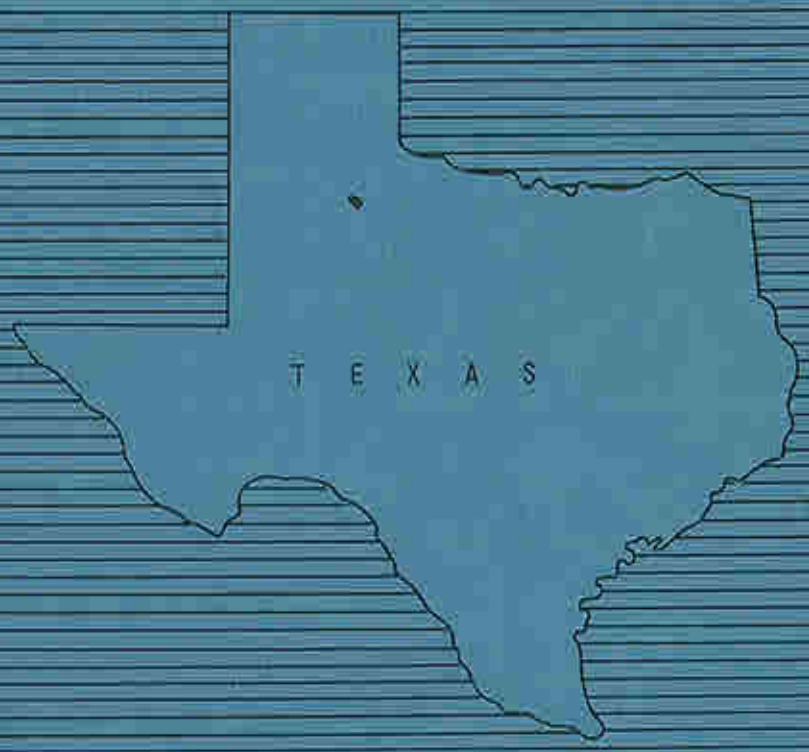
WORK PLAN

FOR WATERSHED PROTECTION
AND FLOOD PREVENTION

DUCK CREEK WATERSHED

DICKENS AND CROSBY COUNTIES, TEXAS



December 1964

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WATERSHED WORK PLAN AGREEMENT

between the

Duck Creek Soil Conservation District
Local Organization

Dickens County Water Control and Improvement District No. 1
Local Organization

Commissioners Court of Dickens County
Local Organization

City of Spur

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 Duck 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; 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 Duck 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 can be installed in about 5 years.

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

1. The percentage of cost to acquire land, easements, or rights-of-way needed in connection with the works of improvement to be borne by the Sponsoring Local Organizations and the Service is as follows:

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Land, Easements, and Rights-of-Way Cost (dollars)
11 Floodwater Retarding Structures	100	0	120,546
1 Multiple-Purpose Structure	100	0	14,545
5 Grade Stabilization Structures	100	0	3,003
7 Streambank Protection Structures	100	0	1,500

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. (Estimated cost- $ 1,800)

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

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Construction Cost (dollars)
11 Floodwater Retarding Structures	0	100	1,174,207
1 Multiple-Purpose Structure	3.2	96.8	154,573
5 Grade Stabilization Structures	0	100	113,863
7 Streambank Protection Structures	0	100	31,020

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

Works of Improvement	Sponsoring Local Organization (percent)	Service (percent)	Estimated Installation Service Cost (dollars)
11 Floodwater Retarding Structures	0	100	257,386
1 Multiple-Purpose Structure	3.2	96.8	30,077
5 Grade Stabilization Structures	0	100	42,018
7 Streambank Protection Structures	0	100	13,046

5. The Sponsoring Local Organization will bear the costs of administering contracts. (Estimated cost $ 9,000 .)

6. The Sponsoring Local Organization will obtain agreements from owners of not less than 60 of the land above each reservoir and floodwater retarding structure that they will carry out conservation farm or ranch plans on their land.

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

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

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

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

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

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

12. The program conducted will be in compliance with all requirements respecting non-discrimination as contained in the Civil Rights Act of 1964 and the regulations of the Secretary of Agriculture (7C.F.R. Sec. 15.1 - 15.13), which provide that no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any activity receiving Federal financial assistance.

13. 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.

14. No member of 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.

Duck Creek Soil Conservation District
Local Organization

By Victor Arrington

Title Chairman

Date May 24, 65

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

adopted at a meeting held on May 13, 1965

J B Morrison Jr
(Secretary, Local Organization)

Date May 24, 1965

4-19987 3-65

Dickens County Water Control and Improvement District No. 1
Local Organization

By [illegible]

Title President

Date May 24, 1965

The signing of this agreement was authorized by a resolution of the governing body of the Dickens County Water Control and Improvement District No. 1
Local Organization

adopted at a meeting held on May 24, 1965

O. D. Hagan
(Secretary, Local Organization)

Date May 24, 1965

Commissioners Court of Dickens County
Local Organization

By Martin Rye

Title County Judge

Date 5-24-65

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

adopted at a meeting held on May 24, 1965

Fred Cunington
(~~Secretary, Local Organization~~)
County Clerk

Date 24 May 1965

City of Spur
Local Organization

By M. A. Ruckila

Title Mayor

Date 5-24-1965

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

adopted at a meeting held on May 10, 1965

Eloise Crockett
(Secretary, Local Organization)

Date May 24, 1965

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

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WORK PLAN

FOR

WATERSHED PROTECTION AND FLOOD PREVENTION

DUCK CREEK WATERSHED
Dickens and Crosby Counties, Texas

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

Prepared By:

Duck Creek Soil Conservation District
(Sponsor)

Dickens County Water Control and Improvement District No. 1
(Sponsor)

Commissioners Court of Dickens County
(Sponsor)

City of Spur
(Sponsor)

With Assistance By:

U. S. Department of Agriculture
Soil Conservation Service
December 1964

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USDA-SCS-FORT WORTH, TEX. 1965

WATERSHED WORK PLAN

DUCK CREEK WATERSHED
Dickens and Crosby Counties, Texas
December 1964

SUMMARY OF PLAN

General Summary

The work plan for watershed protection and flood prevention for the Duck Creek watershed was prepared by the Duck Creek Soil Conservation District, the Dickens County Water Control and Improvement District No. 1, the Commissioners Court of Dickens County, and the city of Spur as sponsoring local organizations. Technical assistance was provided by the Soil Conservation Service of the United States Department of Agriculture.

It is significant that the entire cost of developing this work plan, $60,000, was borne by the Dickens County Water Control and Improvement District No. 1.

The watershed covers an area of 208 square miles, or 133,120 acres, in Dickens and Crosby Counties, Texas. Approximately 47 percent of the watershed is cropland, 1 percent is pasture, 49 percent is rangeland, and 3 percent is in miscellaneous uses such as urban areas, farmsteads, roads, railroad rights-of-way, and stream channels.

There are no Federal lands in the watershed.

The principal problem is one of extensive flooding on the 9,526 acres of flood plain lands along Duck Creek and its tributaries. Major floods causing severe damage to and loss of land and crops have occurred on the average of once every 5 years.

The objectives of the project are to provide proper land use and treatment in the interest of soil and water conservation and flood protection for the flood plain lands along Duck Creek and its tributaries. The project as formulated meets these objectives. The sponsoring local organizations determined that no organized group or individual was interested in including additional water storage for any purpose other than irrigation. The capacity of floodwater retarding structure No. 5 will be increased to provide 198 acre-feet of irrigation storage for an individual landowner.

The work plan proposes installing, in a 5-year period, a project for the protection and development of the watershed at a total estimated installation cost of $3,257,884. The share of this cost to be borne by Public Law 566 funds is $1,810,207. The share to be borne by other than Public Law 566 funds is $1,447,677. In addition, the local interests will bear the entire cost of operation and maintenance.

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Land Treatment Measures

Landowners and operators will establish land treatment during a 5-year period which will help accomplish the project objectives. Primarily, this treatment will consist of measures, or combinations of measures, which contribute directly to watershed protection, flood prevention, and sediment control.

The cost for land treatment is estimated to be $1,298,488, all of which will be borne by other than Public Law 566 funds. This amount includes expected reimbursements from Agricultural Conservation Program Service and Great Plains Conservation Program Cost-Share Funds and $40,471 to be spent by the Soil Conservation Service for technical assistance under its going program during the project installation period.

Structural Measures

The structural measures included in the plan consist of 12 floodwater retarding structures, 5 grade stabilization structures for critical area treatment, and 7 streambank protection structures. The 12 floodwater retarding structures have a total sediment storage and floodwater detention capacity of 28,589 acre-feet. Floodwater retarding structure No. 5 has 198 acre-feet of storage for irrigation purposes. The 5 grade stabilization structures contain incidental storage capacity for 142 acre-feet of sediment and 160 acre-feet for floodwater detention. The streambank protection structures consist of a total of 7,050 feet of revetment constructed of heavy wood posts and smooth wire in combination with plantings of willows and wild plums to divert prolonged stream flows toward the center of the channel. The total estimated installation cost of structural measures is $1,959,396 of which the local share is $149,189 and the Public Law 566 share is $1,810,207. The local share of costs consist of land, easements, and rights-of-way ($134,389); administering of contracts and legal fees ($13,600); and water rights ($1,200). In addition, the local non-project costs for irrigation storage in floodwater retarding structure No. 5 is estimated to be $7,188.

The structural measures will be installed during a 3-year period.

Damages and Benefits

The reduction in floodwater, sediment, flood plain scour, and streambank erosion damages will directly benefit the owners and operators of about 110 farms and ranches in the watershed. Approximately 9,600 acres of agricultural land will benefit from installation of the project.

The estimated average annual floodwater, sediment, erosion, and indirect damages, without a project, total $265,901 at long-term price levels. With the proposed land treatment and structural measures installed, damages from these sources will be reduced to an estimated $76,603 annually. This will be a reduction of 71.2 percent.

The average annual primary benefits accruing to the structural measures are estimated to be $173,295 which are distributed as follows:

Damage reduction benefits	$170,691
Incidental benefits	2,604

Local secondary benefits of $15,609 will result from the project.

The ratio of the total annual benefits ($188,904), resulting from the installation of the structural measures, to the annual cost ($66,854) is 2.8:1.

Benefits from the planned land treatment measures were not evaluated in monetary terms since experience has shown that soil, water, and plant conservation practices produce benefits in excess of their costs.

Provisions for Financing Local Share of Installation Cost

The Dickens County Water Control and Improvement District No. 1 has power of taxation and eminent domain under applicable State laws. A special district tax has been voted for the purpose of securing bond funds in the amount of $100,000 to finance the local share of installation costs of the structural measures and other local costs. The landowner involved will pay to the Dickens County Water Control and Improvement District No. 1 all installation costs of floodwater retarding structure No. 5 allocated to irrigation water supply.

Operation and Maintenance

Land treatment measures for watershed protection will be operated and maintained by the landowners or operators of the farms and ranches on which the measures will be installed under agreement with the Duck Creek Soil Conservation District.

The Dickens County Water Control and Improvement District No. 1 will be responsible for the operation and maintenance of the 12 floodwater retarding structures, the 5 grade stabilization structures, and the 7 structures for streambank protection. Adequate revenue is presently being collected from a special district tax which has been voted for this purpose. The estimated average annual cost of operation and maintenance of all structural measures is $2,420.

DESCRIPTION OF WATERSHED

Physical Data

The main stream of Duck Creek originates in Dickens County, Texas, about four miles east of McAdoo. It flows toward the southeast, passes the edge of the city of Spur, and joins the Salt Fork of the Brazos River in Kent County. Duck Creek watershed, as discussed in this work plan, encompasses an area of 208 square miles or 133,120 acres, including only the drainage area upstream from the Dickens-Kent County line. Major tributaries are Cottonwood Creek, Dockum Creek, Spade Draw, and Wilson Draw.

The topography is quite varied and can be separated physiographically into three distinct parts: the Rolling Plains Land Resource Area; the High Plains Resource Area; and the Cap Rock Escarpment which separates the two land resource areas.

Approximately 80 percent of the watershed lies within the Rolling Plains Land Resource Area. The surface is gently sloping to rolling in the upland and nearly level in the broad alluvial valleys.

A portion of the prominent Cap Rock Escarpment, which forms the eastern edge of the High Plains, occupies about 12 percent of the watershed in the headwater portion. The slopes along the escarpment are 20 to 50 percent. The buttes, canyons, large gullies, and "arroyo like" channels, characteristic of this escarpment, signify geologic instability and the rapid rate at which erosion is advancing into the High Plains.

The High Plains Land Resource Area is characterized by a remarkably flat surface with a general southeastward slope, interrupted by many shallow depressions or sinks. Occasionally, heavy rains fill and overflow these depressions. This causes a small portion of the High Plains to contribute runoff to Duck Creek as water spills over the Cap Rock Escarpment. The area amounts to about eight percent of the watershed.

Elevations in the watershed range from greater than 2,900 feet above mean sea level on the High Plains to about 2,140 feet on the flood plain at the Dickens-Kent County line.

Permian, Triassic, Tertiary, and Quaternary geologic strata are exposed in the watershed. The Permian system is represented by northwesterly dipping beds of red and greenish gray shale, siltstone, and thin-bedded sandstone belonging to the upper section of the Peacock formation of the Double Mountain group. The outcrop of these Permian beds covers the lower 20 percent of the watershed.

The Permian beds are overlain to the northwest by southeasterly dipping Triassic sandstones, conglomerates, and vari-colored shales of the Dockum group. The outcrop of Triassic strata covers about 40 percent of the watershed.

The Triassic beds are in turn overlain by Tertiary and Quaternary beds of the Cap Rock Escarpment and High Plains. These beds, including the Ogallala, Tule, Blanco, and Tahoka formations, consist of sands, gravels, bentonitic clays, and freshwater limestones and cover about 20 percent of the watershed.

Broad valley alluvium and terrace deposits cover about 20 percent of the watershed. These sands, silty sands, clayey sands, and sandy clays are underlain primarily by Permian beds.

The soils in general are deep, fertile, moderately permeable fine sandy loams and clay loams in the valleys; very shallow to deep, moderately to very slowly permeable clay loams in the rolling upland; very shallow to

deep, moderately to moderately rapidly permeable fine sandy loams and clay loams in the Cap Rock Escarpment; and deep to shallow, slowly to very slowly permeable clay loams on the High Plains. The dominant soil series are Spur, Miles, Abilene, Wichita, Weymouth, Vernon, Bippus, Mansker, Potter, and Pullman.

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

Land Use	Acres	Percent
Cropland	63,011	47.3
Pasture	1,505	1.1
Rangeland	65,055	48.9
Miscellaneous 1/	3,549	2.7
Total	133,120	100.0

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

The soils of the flood plain and adjacent terrace deposits are intensively cultivated. The crops are primarily row crops which produce little effective hydrologic cover, but conservation practices such as grasses and legumes in rotation, cover and green manure crops, mulching, crop residue use, terracing, and contour farming have been effective in reducing rates of erosion and runoff.

In the upper portion of the watershed, rapid sheet erosion is occurring on scattered fields of rolling cropland in land capability class VI. This is occurring mostly on medium and coarse textured soils with slopes ranging from 3 to 5 percent. Most of these fields are expected to be converted to pastureland during the next 5 years.

The hydrologic cover condition on rangeland is mostly fair to good. Range sites within the watershed are Deep Hardland, Sandy Loam, Very Shallow, Shallow, Redland, Sandyland, Gypland, Hardland Slopes, Mixedland Slopes, Rough Broken Heavy, Rough Broken Sandy, and Bottomland. The most desirable grasses, with decrease as grazing increases, include blue grama, sideoats grama, little bluestem, and vine mesquite. Increasers include buffalograss, perennial threeawn, tobosa, hairy grama, and sand dropseed. Vegetation which invades following overuse to heavy use of rangeland includes mesquite, yucca, pricklypear cactus, Texas and red grama, hairy tridens, and redberry juniper. Presently, the most abundant grasses are buffalograss, blue grama, sideoats grama, and tobosa. Woody vegetation is generally sparce.

The climate is warm and semi-arid. Mean monthly temperatures range from 42 degrees Fahrenheit in January to 82 degrees in July. The normal growing season, extending from March 19 to November 16, is 242 days. The average annual rainfall is 21.36 inches. Monthly averages range from 2.96 inches in September to 0.55 inch in January. The heaviest rainfall period extends from April through October. Much of the rain falls as intense local showers, resulting in rapid runoff and severe soil erosion.

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Wells are the principal source of water for municipal, irrigation, rural domestic, and livestock use. The most important water bearing sands are in the Recent and Pleistocene valley alluvium of Duck Creek and its larger tributaries. This water, although hard, is suitable for irrigation and municipal uses. Surface ponds are another source of water for livestock and some irrigation.

Economic Data

The economy of the watershed depends almost entirely on agricultural production. The watershed is characterized by intensive farming operations with irrigation water from shallow wells contributing to a large share of the production of crops. Irrigation has increased rapidly during the last 10 years, but future increase will be considerably reduced by the limited supply of ground water. The principal crops are cotton, grain sorghum, wheat, and hay crops of sudan and alfalfa. It is expected that the present land use will continue; however, some of the less productive upland will be converted from crops to pasture and range to promote more efficient operations.

The flood plain and adjacent areas are made up of small family type farms while the remaining upland areas are generally comprised of larger farms and ranches. The average size farm in the watershed is about 250 acres and represents an investment of approximately $51,000.

Estimated value of flood plain land is $200 to $600 per acre and the value of the upland ranges from $50 to $150 per acre.

More than half of the farms are owner-operated. Most farms constitute an economical unit and have the productive capacity to provide a good living for the operator. There are no farms in the watershed that have total sales of less than $2,500 annually.

Cotton, wheat, and grain sorghum are the crops in surplus supply being produced in the watershed. The acreage now devoted to these crops is significant to the watershed economy and to the producers who depend upon these crops for a major portion of the family income.

The agricultural economy of the watershed is strong. Most farmers have a net income in the $5,000 to $9,999 bracket; however, there is a segment of the population that is in a low income bracket. This segment includes the workers who depend upon farm and farm related activities for their employment. Much of the present employment is seasonal in nature and is based on production, harvesting, and processing of agricultural products. A crop failure caused by floods, droughts, or insects has a substantial impact on the income of these workers. Additional employment opportunities are needed in this area to better utilize the available workers.

The principal town in the watershed is Spur with a population of 2,170 (1960 census) which has remained unchanged for the last 10 years. The main businesses, other than regular retail stores, are cotton gins, cotton compress, seed, fertilizer, and farm equipment dealers. The economy of Spur is almost entirely based on the agricultural activity of the watershed.

There are about 157 miles of roads, of which about 60 miles are hard surface. Local markets can be reached from all parts of the watershed. U. S. Highway 82 and State Highway 70 cross the watershed.

Land Treatment Data

The Soil Conservation Service work unit at Spur is assisting the Duck Creek Soil Conservation District. There are 338 operating units in the watershed, of which 242 units, 93,837 acres, are under district agreement. The work unit has assisted Soil Conservation District cooperators in preparing 202 basic soil and water conservation plans covering 85,588 acres and has given technical assistance in establishing and maintaining planned measures. Current revision is needed on 100 conservation plans. Soil surveys have been completed on the entire watershed. Approximately 60 percent of the needed land treatment practices for the 129,571 acres of agricultural land have been applied. It is estimated that the level of land treatment will reach 80 percent in 5 years as a result of the planned land treatment program.

WATERSHED PROBLEMS

Floodwater Damage

An estimated 9,526 acres of the watershed, excluding stream channels, is flood plain (figure 1). As described herein, the flood plain is the area that will be inundated by runoff from a 100-year frequency storm. Land use in the flood plain is 69 percent cropland, 4 percent pasture, 19 percent rangeland, 5 percent idle, and 3 percent miscellaneous.

Flooding from Duck Creek and its tributaries causes severe damage to growing crops and other agricultural properties. Severe damage also is inflicted on nonagricultural property such as roads and bridges, especially by the larger storms. Flood plain erosion and sediment deposits have caused substantial acreages of flood plain land to be left idle and limited the use of a great many more acres. In the past, major floods, inundating more than half of the flood plain, have occurred in 1957, 1953, 1948, 1946, 1942, 1937, and 1932. A great many minor floods, covering less than half the flood plain, also occurred during this period. Most floods occur during April, May, and June which is the season when crops are at a critical stage in growth and are very susceptible to damage from floodwater.

Flood plain land is very fertile and is used intensively. Irrigated crops are produced on about a fourth of the floodplain. Expensive improvements, in connection with the intensive type of farming, have been installed. Consequently, floods cause high other agricultural damage in the flood plain. The topography and other characteristics of the watershed cause the floods to develop rapidly and produce peaks that are very destructive. Such a flood occurred in 1953 and again as recently as 1957. In addition to crop losses, sediment, erosion, other agricultural and nonagricultural damages were extremely severe from these floods.

During a 100-year period, floodwater is expected to inundate, on the average, 3,147 acres from a 1-year frequency storm, 4,328 acres from a

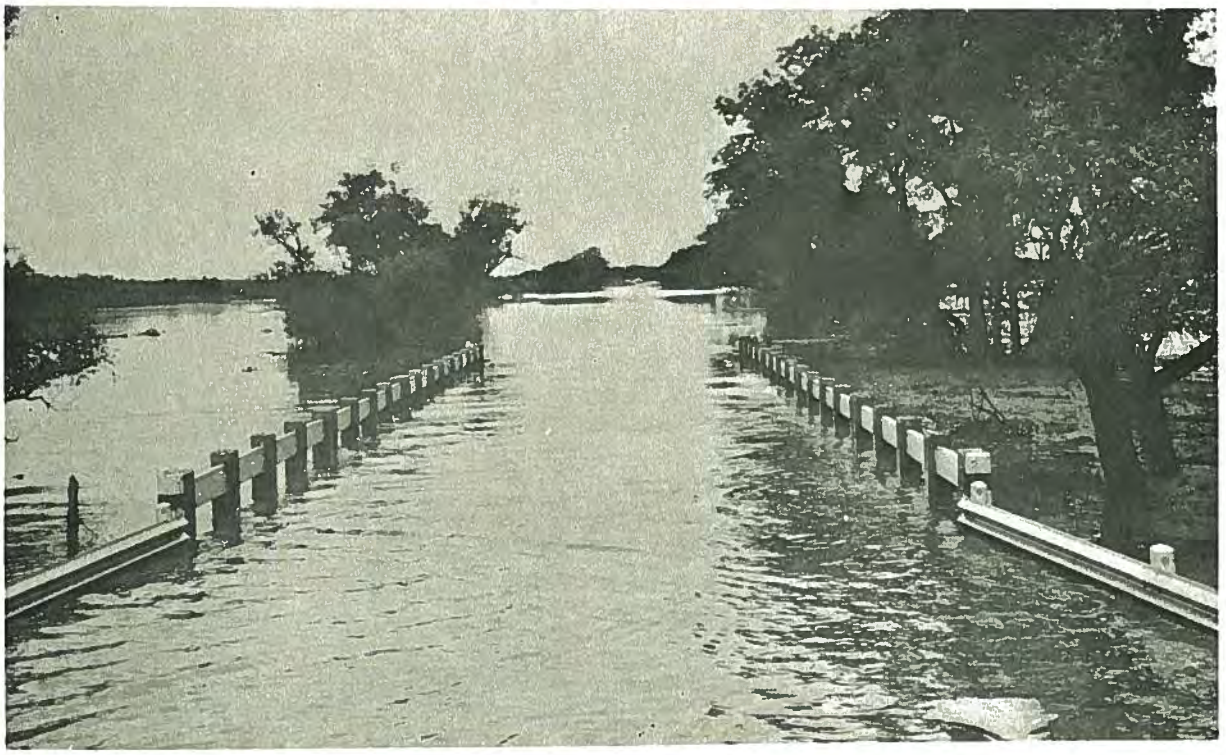

PHOTO COURTESY GRADY JOE HARRISON

Flooding on Wilson Draw in 1958, showing bridge on State Highway 70 six miles southeast of Spur (figures 1 and 5).

PHOTO COURTESY JOHN F. MOORE

Flooding on Duck Creek, October 1953, south of State Highway 70 three miles southeast of Spur (figures 1 and 5).

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2-year frequency storm, 6,290 acres from a 5-year frequency storm, 7,164 acres from a 10-year frequency storm, 8,023 acres from a 25-year frequency storm, and 8,765 acres from a 50-year frequency storm. Cumulative totals of recurrent flooding indicate an average annual flooding of 6,483 acres during the evaluation period.

Based on the flooding expected to occur during the 100-year evaluation period, the total direct floodwater damage is estimated to average $163,162 annually at long-term price levels (table 5). Of this amount, $117,569 is crop and pasture damage; $26,692 is other agricultural damage; and $18,901 is nonagricultural damage to roads and bridges.

Indirect damages such as interruption of travel, re-routing of school bus and mail routes, losses sustained by business in the area, and similar losses are estimated to average $24,173 annually.

Sediment Damage

Sediment damage is severe in the watershed. The most damaging sediment consists of fine to medium grained sand which originates primarily in the Pliocene and Pleistocene beds exposed in the Cap Rock Escarpment and along critically eroding streambanks. The severity of movement and deposition of this sediment is evident in large colluvial deposits, the great volume of stream bedload, and the thick and extensive overbank deposits on the flood plain.

Some meanders of Duck Creek have become so completely filled with sediment that flood flows, following the path of least resistance, have eroded new channels across valuable cropland.

A long segment of Dockum Creek has lost practically all of its channel capacity through sedimentation. This has greatly increased the frequency and severity of flooding.

There are formerly cultivated fields on the Duck Creek flood plain with fertile fine sandy loam soils buried beneath deposits of sterile sand ranging up to six feet in thickness.

Overbank deposition of sediment ranges from one to eight feet in thickness and from sandy clay to medium grained sand in texture. It is estimated that overbank deposition causes a substantial loss of productivity on an average of 2,901 acres of flood plain land annually and that this damage is increasing. The following tabulation shows average annual overbank deposition damage by evaluation reaches:

Aerial view of critically eroding gully on tributary of Cottonwood Creek (CA-3, figure 5).

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PHOTO COURTESY JOHN H. TAYLOR

Critical streambank erosion at this segment of Dockum Creek results in an average annual loss of 1.5 acres of valuable cropland (No. 107, figure 5).

PHOTO COURTESY JOHN H. TAYLOR

Sediment deposition on cultivated field following heavy rain.

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Average Annual Acres Damaged by Overbank Deposition of Sediment

Evaluation: Reach (Plate 1)	Percent Reduction in Productive Capacity 10	20	30	40	50	60	70	Total Acres
1	0	0	0	260	218	0	0	478
2	0	0	592	0	0	0	0	592
3	17	57	131	118	0	0	42	365
4	30	110	24	0	36	27	23	250
5	78	0	77	14	33	0	0	202
6	0	30	0	0	0	0	0	30
7	35	22	0	0	0	0	0	57
8	341	250	142	93	95	0	0	921
9	0	0	0	0	0	0	0	0
10	6	0	0	0	0	0	0	6
TOTAL ACRES	507	469	966	485	382	27	65	2,901

The average annual monetary value of this damage is estimated to be $70,596 at long-term price levels (table 5).

Erosion Damage

The estimated average annual rate of gross erosion is 3.42 acre-feet per square mile. Of this, sheet erosion accounts for 69 percent, streambank erosion 13 percent, gully erosion 8 percent, flood plain scour 6 percent, and streambed erosion 4 percent.

The most rapid rate of erosion is occurring in the Cap Rock Escarpment. Large gullies are eroding headward at average annual rates ranging from 2 to 65 feet. Stream channels are widening at average annual rates ranging up to two feet. The average annual soil loss at five critical sediment source areas (figure 1) is eight acre-feet.

Farther downstream, very active streambank erosion is occurring along some sharp bends of Duck, Cottonwood, and Dockum Creeks. The average annual lateral erosion at these sharp bends ranges from 17 to 58 feet. The soil loss averages 64 acre-feet annually. This critical streambank erosion is responsible for an average loss of about 6 acres of valuable irrigated cropland annually. The average annual monetary value of this damage is estimated to be $2,695 at long-term price levels (table 5).

Large volumes of sand move downstream as bedload during high flows. However, the channels remain in a near stable condition since additional bedload is moved in to replace that which has been removed.

The area affected by flood plain erosion is small. Most of the damaged areas range from broad sheet scour depressions to channels one to six feet deep. It is estimated that flood plain scour causes loss of productivity on an average of 350 acres of flood plain land annually and is distributed as follows: 136 acres, 10 percent; 138 acres, 20 percent; and 76 acres,

30 percent. The average annual monetary value of this damage is estimated to be $5,275 at long-term price levels (table 5).

Problems Relating to Water Management

Local interests recognize a need for water based recreation. Population in the local area is about 10,625. Population within a 40-mile radius is about 25,000 and no water based recreation facilities exist at present other than White River Reservoir. There is a desire to conserve and utilize water throughout the watershed. The city of Spur has completed arrangements to obtain municipal water from the White River Reservoir. There is no known need for drainage or for additional storage for municipal or industrial water supply.

Irrigation water is obtained from shallow wells in the flood plain and adjacent alluvium; however, additional water is desired for irrigation in areas near some floodwater retarding structure sites. Water levels in some irrigation wells are lowered during the peak pumping season creating temporary shortage of water when the need is critical.

PROJECTS OF OTHER AGENCIES

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

The works of improvement included in this plan will have no known detrimental effects on any existing or proposed downstream works of improvement.

BASIS FOR PROJECT FORMULATION

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

Meetings were held with the sponsoring local organizations to discuss existing flood problems and water and related land resource development needs, including recreation and irrigation, and to formulate project objectives. Watershed protection, flood prevention, and storage of water for irrigation were the primary objectives desired by the sponsors. Also, the sponsors expressed interest in investigations to determine the feasibility of increasing ground water recharge.

The following specific objectives were agreed to:

1. Establish land treatment measures which contribute directly to watershed protection and flood prevention and would make the watershed an outstanding example of soil and water conservation.

2. Establish special treatment of critically eroding gullies and streambanks.

3. Attain a reduction of at least 70 percent in average annual flood damages.

4. Include storage of water for irrigation in any structure, where the landowner involved would be willing to bear that portion of the structure cost allocated to irrigation.

The land treatment program would include conversion of cropland to pastureland, resulting in a reduction in surplus crop production.

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

Consideration was given to the inclusion of measures for ground water recharge. Investigations indicated that recharge of the shallow aquifer approaches a maximum during periods of low demand. Consequently, no structural measures designed specifically for ground water recharge are included in the project.

The recommended works of improvement, including both land treatment and structural measures, meet the project objectives at least cost in providing the desired level of protection to agricultural flood plain lands. Storage of water for irrigation will be included in one of the floodwater retarding structures. The sediment pools of floodwater retarding structures open to the public will provide incidental recreational benefits at no additional cost.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

The Duck Creek Soil Conservation District is assisting farmers and ranchers of the watershed in the preparation and application of basic soil and water conservation plans on their land. The application of measures in these plans, which are based upon the use of each acre within its capabilities and treatment in accordance with its needs, is an essential part of a sound program for watershed protection and flood prevention. The extent of needed land treatment measures which have been applied to date within the watershed represents an estimated expenditure by landowners and operators of $1,505,861, including reimbursements from ACPS (table 1A).

The accelerated application and continued maintenance of land treatment measures is particularly important for protection of the 69,376 acres which comprise the drainage areas above planned floodwater retarding structures.

The land treatment measures will reduce the capacity required for sediment accumulation in planned structural measures. They also will reduce the rate of runoff into floodwater retarding structures. About 54,538 acres of upland below the planned floodwater retarding structures contribute sediment

PHOTO COURTESY JOHN F. MOORE

Level closed-end terrace functioning after heavy rain. This measure slows runoff from fields, conserves water, and reduces erosion damage and sediment production.

Former cropland converted to grassland by planting Switchgrass and Indian Grass.

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PHOTO COURTESY JOHN H. TAYLOR

Range improvement through brush control, deferred grazing, and proper range use.

PHOTO COURTESY JOHN H. TAYLOR

Stubble mulching keeping protective amounts of vegetative material on the surface of the soil.

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and runoff to the flood plain areas. Land treatment measures on these lands will further reduce floodwater and sediment damages on 9,526 acres of flood plain.

Table 1 includes estimates of the acreage in each major land use on which land treatment measures will be established during the 5-year project installation period. These measures will be established and maintained by landowners and operators in cooperation with the Duck Creek Soil Conservation District. The local people will continue to install and maintain land treatment measures needed in the watershed after the 5-year installation period. A complete standard soil survey of the watershed has been made.

About 11,700 acres of cultivated land will be treated with a combination of measures in keeping with a conservation cropping system for soil conditioning and protection from sheet erosion in the upland and from scour in the flood plain. The conservation cropping systems in this watershed include grasses and legumes in rotation, cover and green manure crops, mulching, fertilizing, and crop residue use. About 76 miles of terraces provided with grassed waterways will be installed to control erosion and retard runoff from the more rolling areas. Surface and sprinkler irrigation systems, land leveling, and irrigation water management will be installed on about 1,700 acres for efficient application and distribution of irrigation water.

There is a trend toward conversion of rolling and eroded cropland to pasture. Proper use will be practiced on about 1,950 acres of new pastureland converted from cropland. These acres will receive plantings of desirable forage plants to attain a good base cover.

About 11,400 acres of rangeland will be either bulldozed, root plowed, or sprayed to control brush, and 150 acres will be seeded with range grasses. Deferred grazing will be practiced on about 13,000 acres. The destruction of cover caused by over-use around present watering places will be reduced by establishing 10 farm ponds.

The installation of all land treatment measures will reduce average annual erosion by about 20 percent and increase infiltration of rainfall as a result of improved ground cover in cultivated areas and increased grass density and vigor in pastured areas. Terraces, diversions, and waterways will have a measurable effect in slowing the runoff from cultivated fields and in reducing erosion damage and sediment production. Also, the conversion of rolling cropland to pastureland will result in a reduction in surplus crop production.

Structural Measures

A system of 12 floodwater retarding structures, 5 grade stabilization structures, and 7 structures for streambank protection will be installed to afford the needed protection to flood plain lands that cannot be attained by land treatment measures alone. A floodwater diversion, approximately 9,265 feet long, is to be constructed and considered as part of floodwater retarding structure No. 6. The estimated installation cost of these

structural measures is $1,959,396.

The landowner on whose land floodwater retarding structure No. 5 is located plans to increase the storage capacity of the site by 198 acre-feet. The additional water is to be used for irrigation. A non-project cost of $7,188 will be borne by the landowner for this additional storage.

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

The location of structural measures is shown on the project map (figure 5).

The storage capacity of the 12 floodwater retarding structures and the 5 grade stabilization structures will be 29,089 acre-feet. Of this total, 10,281 acre-feet of storage will be provided for sediment accumulation during a 100-year period in the floodwater retarding structures and 142 acre-feet of incidental storage capacity for sediment accumulation in the 5 grade stabilization structures. Also included in the total storage capacity of the structural measures is 198 acre-feet for irrigation water and 18,468 acre-feet for floodwater detention. Runoff from 52 percent of the watershed will be retarded. This is an average of 3.17 inches of runoff from the area upstream from the floodwater retarding structures. The capacity equivalents for each structure are shown in tables 3 and 3A.

The 5 stabilization structures are pipe drop inlets designed to submerge existing overfalls. As a safety feature of construction in the easily eroded soils, the stabilization structures are designed for a two percent chance of use of the emergency spillways. This results in incidental sediment storage capacities in these structures.

The 7 streambank protection structures will consist of a total of 7,050 feet of revetment constructed of heavy wood posts and smooth wire in combination with plantings of willows and wild plums to divert prolonged stream flows toward the center of the channel.

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

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

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

Some basic facilities for incidental recreation will be installed at selected sites by landowners.

EXPLANATION OF INSTALLATION COST

Technical assistance for the installation of planned land treatment for watershed protection will be provided, in the amount of $40,471 during the

5-year installation period, by Public Law 46 funds under the going program. Local interests will apply the planned land treatment, including recurring practices, at an estimated cost of $1,258,017, which includes reimbursements from Agricultural Conservation Program Service and Great Plains Conservation Program Cost-Share Funds based on present program criteria (table 1). The costs are based on present prices being paid by landowners or operators to establish the individual measures in the area. The land treatment necessary to reach treatment goals and the unit cost of each measure were estimated by the Duck Creek Soil Conservation District.

The total installation cost of the structural measures is estimated to be $1,959,396. Of this total, $1,468,655 is for construction; $341,552 is for installation services; $138,989 is for land, easements, and rights-of-way; $9,000 is for administration of contracts; and $1,200 is for water rights. Public Law 566 cost share is $1,810,207 which include $1,468,655 for construction and $341,552 for installation services. Local cost share is $149,189 which include $136,289 for value of land, easements, and legal fees, $1,800 for changes in utilities, $900 for relocating improvements, $9,000 for contract administration, and $1,200 for water rights.

Construction costs include the engineer's estimate and contingencies. The engineer's estimates were based on the unit costs of floodwater retarding structures in similar areas modified by special conditions inherent to each individual site location. They include such items as permeable foundation conditions, rock excavation, wasting unsuitable material, and site preparation. Ten percent of the engineer's estimate was added as a contingency to provide funds for unpredictable construction costs.

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

A local landowner desires to store additional water in floodwater retarding structure No. 5 for irrigation water supply. The total non-project cost for this storage is estimated to be $7,188. This includes a value of $605 for land and $600 for water rights. The remaining $5,983 is the pro rata part of the construction and installation services costs allocated to irrigation by "Use of Facilities" method.

Public Law 566 funds will bear all project construction and installation services costs of the structural measures. Other funds will bear all the costs of land, relocation and modification of existing improvements, administration of contracts, legal fees, and water rights.

The estimated schedule of obligations for the 5-year installation period, covering installation of land treatment and structural measures is as follows:

Schedule of Obligations

Fiscal Year	Measures	Public Law 566 Funds (dollars)	Other Funds (dollars)	Total (dollars)
1st	Floodwater Retarding Structures Nos. 1, 2, 6, and 7	690,545	42,206	732,751
	Critical Areas Nos. 1 and 2	70,306	2,355	72,661
	Land Treatment	0	194,773	194,773
2nd	Floodwater Retarding Structures Nos. 3, 4, 5, and 11	457,978	38,646	496,624
	Critical Areas Nos. 3, 4, and 5	85,575	3,148	88,723
	Land Treatment	0	259,698	259,698
3rd	Floodwater Retarding Structures Nos. 8, 9, 10, and 12	461,737	60,834	522,571
	Streambank Protection Structures Nos. 101, 102, 103, 104, 105, 106, and 107	44,066	2,000	46,066
	Land Treatment	0	324,622	324,622
4th	Land Treatment	0	324,622	324,622
5th	Land Treatment	0	194,773	194,773
	Total	1,810,207	1,447,677	3,257,884

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

EFFECTS OF WORKS OF IMPROVEMENT

The project will directly benefit the owners and operators of approximately 110 farms and ranches in the watershed. Approximately 9,600 acres of agricultural land will benefit from installation of the project.

The combined program of land treatment and structural measures will prevent flood damage on 3,818 acres from a 100-year frequency storm, 3,762 acres from a 50-year frequency storm, 3,557 acres from a 25-year frequency storm, 3,316 acres from a 10-year frequency storm, 2,964 acres from a 5-year frequency storm, 1,843 acres from a 2-year frequency storm, and 2,150 acres from a 1-year frequency storm. The average annual flooding from storms of less than 1-year frequency will be reduced from 1,545 acres to 291 acres. Cumulative totals of average recurrent flooding will be prevented on 3,650 acres annually during the evaluation period. In addition, the depth of the remaining flooding will be reduced substantially.

Reductions in area inundated varies with respect to location within the watershed. The general locations and reductions in inundations are shown in the following tabulations:

Average Annual Area Inundated

Evaluation Reach (Figure 1)	General Location	Without Project (acres)	With Project (acres)	Reduction (percent)
1	Duck Creek upstream to Wilson Draw	1,157	585	49.4
2	Duck Creek from Wilson Draw to Spade Draw	1,519	769	49.4
3	Duck Creek from Spade Draw to Dockum Creek	863	355	58.9
4	Duck Creek from Dockum Creek to Cottonwood Creek	246	51	79.3
5	Duck Creek from Cottonwood Creek to Site No. 1	89	3	96.6
6	Wilson Draw	162	49	69.8
7	Spade Draw	86	13	84.9
8	Dockum Creek	2,251	903	59.9
9	Cottonwood Creek 1/	-	-	-
10	Salt Draw 2/	110	105	4.5
	TOTAL	6,483	2,833	56.3

1/ No flood plain land is contained in this reach.

2/ No structural control is planned on Salt Draw.

Area Inundated

Evaluation Reach (Figure 1)	Average Recurrence Interval													
	100-Year		50-Year		25-Year		10-Year		5-Year		2-Year		1-Year	
	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)	Without Project (acres)	With Project (acres)
1	1,095	980	1,067	942	1,040	917	994	885	960	841	882	620	770	120
2	1,537	1,418	1,501	1,363	1,464	1,288	1,414	1,150	1,360	1,035	1,135	810	920	160
3	1,280	1,038	1,225	847	1,159	680	1,075	508	955	422	584	281	380	152
4	956	379	719	245	518	177	353	131	268	62	167	40	64	0
5	545	97	373	33	220	14	170	0	128	0	63	0	11	0
6	195	141	184	108	170	77	150	68	135	64	107	41	86	13
7	310	120	268	112	216	100	157	68	120	0	78	0	0	0
8	3,397	1,327	3,225	1,153	3,043	1,024	2,678	869	2,238	777	1,209	598	883	521
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	211	208	203	200	193	189	173	169	126	125	103	95	33	31
TOTAL	9,526	5,708	8,765	5,003	8,023	4,466	7,164	3,848	6,290	3,326	4,328	2,485	3,147	997

The average annual volume of damaging sediment deposited upon the flood plain is expected to be reduced an estimated 84 percent with the project installed. About 13 percent of this reduction will result from the installation of planned land treatment.

Average annual flood plain erosion consisting of flood plain scour and streambank erosion is expected to be reduced an estimated 60 percent.

Present owners and operators of flood plain land say that if adequate flood protection is provided, particularly through a reduction in flood plain sediment and scour, they will restore most of the now idle land and low producing grassland to improved range and pasture land. It is not anticipated that any flood plain lands that have never been in crop production will be converted as a result of project installation.

Shifts in land use will reduce the total acreage of cropland in the watershed by about 2,341 acres during the project installation period. The acreage of cotton will be reduced by about 550 acres; grain sorghum will be reduced by about 874 acres; and wheat will be reduced by about 327 acres. Decreases in cropland will result from conversions in the pool areas of the floodwater retarding structures and from conversion of cropland, including some idle cropland, to grassland as a result of the planned land treatment program.

Some loss of wildlife habitat will result from the clearing of sediment pools of sites; but all sites will offer opportunities for fish production and furnish habitat for waterfowl. Floodwater detention pool areas will be more favorable than adverse to wildlife. Wildlife habitat in the flood plain will be improved by reduction of frequency, depth and duration of flooding.

Excellent opportunities for the development of on-farm income-producing recreation facilities will become available at and in the vicinity of sediment pools.

Floodwater retarding structure No. 5 will include storage for irrigation water that is expected to be adequate to irrigate 50 acres of cropland annually.

The sediment pools of the floodwater retarding structures, open to the general public, will provide needed water based recreation activities such as fishing and hunting, for many of the local inhabitants. These activities will be enjoyed by an estimated 1,300 people resulting in about 3,750 visitor days use annually. The most intensive use will be during the period of May through September. Average use on peak days for the weekends is expected to be about 100 persons. Some pools will be open on a fee-charge basis and others by free admission with the landowners permission.

There will be 4,139 acre-feet of initial storage in the sediment pools that will be available for incidental uses such as livestock water and domestic uses, and for irrigation when water rights are obtained. It is expected that 196 acres of cropland will receive supplemental irrigation water

annually from the sediment pools of structures.

The project will create additional employment opportunities for the local residents. Employees will be needed for construction and operation and maintenance of the structural measures. Secondary benefits, including increased business activities and improved economic conditions in the area, will result from the installation of the project. Local businesses will benefit from sales and services associated with more uniform production and marketing of agricultural products and from stimulated sales of items needed for water based recreation activities.

This project is not expected to have a significant effect upon the availability of water for the dilution of wastes in the Brazos River.

PROJECT BENEFITS

Total average annual project benefits are estimated to be $207,511, distributed as follows:

Benefits	Dollars
Damage Reduction	189,298
Incidental	2,604
Secondary	15,609

The estimated average annual monetary floodwater, sediment, erosion, and indirect damages (table 5) within the watershed will be reduced from $265,901 to $76,603 by the proposed project. This is a reduction of 71.2 percent, 90 percent of which will result from installation of the structural measures.

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

Average Annual Damage

Evaluation: Reach (Figure 1)	General Location	Without Project (dollars)	With Project (dollars)	Reduction (percent)
1	Duck Creek upstream to Wilson Draw	55,146	17,439	68.4
2	Duck Creek from Wilson Draw to Spade Draw	67,183	24,230	63.9
3	Duck Creek from Spade Draw to Dockum Creek	49,407	14,100	71.5
4	Duck Creek from Dockum Creek to Cottonwood Creek	21,151	2,646	87.5
5	Duck Creek from Cottonwood Creek to Site No. 1	9,059	111	98.8
6	Wilson Draw	3,028	572	81.1
7	Spade Draw	1,349	155	88.5
8	Dockum Creek	57,670	15,691	72.8
9	Cottonwood Creek	157	0	100.0
10	Salt Draw	1,751	1,659	5.3
	TOTAL	265,901	76,603 1/	71.2

1/ Includes damages on Salt Draw for which no structural control is planned.

The annual monetary value of the incidental benefits is expected to be $2,604 including $1,096 from recreation and $1,508 from incidental irrigation. The recreation benefits are based on an estimated 3,750 visitor-days annually at a gross value of one dollar per visitor-day for 750 days use at one site and fifty cents per visitor-day for 3,000 days use at the remaining sites open for public use. The incidental irrigation benefits are based on the value of the increased net income from land to be irrigated with water contained in the sediment pools of floodwater retarding structures Nos. 1 and 5. Allowances were made for associated costs and for lag in accrual of incidental benefits.

It is estimated the project will produce local secondary benefits averaging $15,609 annually. Secondary benefits from a national viewpoint were not considered pertinent to the economic evaluations.

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

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The total annual benefits from the structural measures are estimated to be $188,904. In addition to the monetary benefits, there are other substantial benefits which will accrue to the structural measures such as an increased sense of security, better living conditions, and improved wildlife habitat. None of these benefits were evaluated in monetary terms.

COMPARISON OF BENEFITS AND COSTS

The total average annual cost of structural measures (amortized total installation cost, plus operation and maintenance) is estimated to be $66,854. These measures are expected to produce average annual primary benefits of $173,295 or $2.59 for each dollar of cost.

The ratio of total average annual benefits, including secondary benefits, ($188,904) to the average annual costs of structural measures ($66,854) is 2.8 to 1 (table 6).

PROJECT INSTALLATION

Land treatment (table 1) will be established by farmers and ranchers during a 5-year period in cooperation with the Duck Creek Soil Conservation District. Approximately 60 percent of needed land treatment has been applied. The goal is to treat adequately 80 percent of the land during the installation period. In reaching this goal, it is expected that accomplishments will progress as follows:

Land Use	FISCAL YEAR 1st	2nd	3rd	4th	5th	Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Cropland	1,755	2,340	2,925	2,925	1,755	11,700
Pastureland	292	390	488	487	293	1,950
Rangeland	1,950	2,600	3,250	3,250	1,950	13,000
Total	3,997	5,330	6,663	6,662	3,998	26,650

Technical assistance in the planning and application of land treatment is provided under the going program of the district. A standard soil survey for the watershed has been completed.

The governing body of the Duck Creek Soil Conservation District will assume aggressive leadership in getting the land treatment program underway. The landowners and operators will be encouraged to apply and maintain soil and water conservation measures on their farms and ranches. District owned equipment will be made available to the landowners in accordance with existing agreements for equipment usage in the district.

Special emphasis will first be placed on getting a high degree of land treatment in the drainage areas of floodwater retarding structures. Then the emphasis will be on the land outside drainage areas of structures.

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

The Dickens County Water Control and Improvement District No. 1 has the right of eminent domain by virtue of applicable State law and has the financial resources to fulfill its responsibilities.

The Dickens County Water Control and Improvement District No. 1 will:

1. Obtain the necessary land, easements, rights-of-way, and permits for the structural measures to be dedicated to the Dickens County Water Control and Improvement District No. 1;

2. Determine the legal adequacy of the easements and permits for construction of the structural measures;

3. Provide for the relocation or modification of utility lines and systems, roads, and privately owned improvements necessary for the installation of the structural measures and provide for the necessary improvement of low water crossings on public roads to make them passable during prolonged release flows from the structures or obtain permission to inundate such roads where equal alternate routes are designated for use during periods of inundation;

4. Provide the necessary legal, administrative, and clerical personnel, facilities, supplies, and equipment to advertise, award, and administer contracts and be the contracting agency to let and service contracts for the structural measures.

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

The structural measures will be constructed during a 3-year installation period in the general sequence as follows:

First Year - Floodwater Retarding Structures Nos. 1, 2, 6, and 7;
Grade Stabilization Structures Nos. 1 and 2

Second Year- Floodwater Retarding Structures Nos. 3, 4, 5, and 11;
Grade Stabilization Structures Nos. 3, 4, and 5

Third Year - Floodwater Retarding Structures Nos. 8, 9, 10, and 12;
Streambank Protection Structures Nos. 101 through 107

FINANCING PROJECT INSTALLATION

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

Funds for the local share of the cost of this project will be provided by the Dickens County Water Control and Improvement District No. 1.

The voters of Duck Creek watershed have approved a tax of 80 cents on each $100 of assessed property valuation. This is being levied and collected annually to secure bond funds in the amount of $100,000 for the local share of the installation cost of the planned structural measures and other costs including establishment of a reserve fund for maintenance. Revenue from the sale of these bonds will be available and adequate for financing the share of project installation costs to be borne by local interests.

The portion of cost for floodwater retarding structure No. 5 allocated to irrigation is a non-project cost. The landowner involved will pay the amount of these costs to the Dickens County WCID No. 1 prior to issuance of invitation to bid. The amount, estimated at $5,983, includes $5,008 for construction and $975 for installation services.

It is anticipated that approximately 85 percent of the easements for the structural measures will be donated. The out-of-pocket costs of easements, relocation of utilities, roads and improvements, legal services, and administration of contracts is estimated to be $37,253.

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

Structural measures will be constructed during a 3-year installation period pursuant to the following conditions:

1. The requirements for the land treatment in the drainage area above the floodwater retarding structures and the multiple-purpose structure have been satisfied.

2. All lands, easements, rights-of-way, and permits have been obtained for all structural measures or a written statement is furnished by the Dickens County Water Control and Improvement District No. 1 that their rights of eminent domain will be used, if needed, to secure any remaining land, easements, or rights-of-way within the project installation period and that sufficient funds are available for purchasing those easements and rights-of-way.

3. Water rights have been obtained for storage of irrigation water in floodwater retarding structure No. 5.

4. Court order has been obtained from the Dickens County Commissioners Court showing that the county road affected

by the detention and sediment pool of floodwater retarding structure site No. 8 will either be relocated or raised to elevation 2449.1 at no expense to the Federal Government, or permission granted to temporarily inundate the road provided equal alternate routes are available.

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

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

7. The contracting agencies are prepared to discharge their responsibilities.

8. The project agreements have been executed.

9. Operation and maintenance agreements have been executed.

10. Public Law 566 funds are available.

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

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

The County Agricultural Stabilization and Conservation committee will cooperate with the governing body of the soil conservation district by selecting and providing financial assistance for those practices which will accomplish the conservation objectives in the shortest possible time.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by landowners and operators of the farms and ranches on which the measures are applied under agreement with the Duck Creek Soil Conservation District. Representatives of the soil conservation district will make periodic inspections of the land treatment

measures to determine maintenance needs and encourage landowners and operators to perform maintenance. They will make district-owned equipment available for this purpose in accordance with existing working arrangements.

Structural Measures

The Dickens County Water Control and Improvement District No. 1 will be responsible for the operation and maintenance of the 12 floodwater retarding structures, the 5 grade stabilization structures, and the 7 structures for streambank protection.

The estimated average annual cost of operation and maintenance of the structural measures is $2,420. Funds are available and adequate for this purpose.

The structural measures will be inspected at least annually and after each heavy rain by representatives of the Dickens County Water Control and Improvement District No. 1 and the Duck Creek Soil Conservation District. A Soil Conservation Service representative will participate in these inspections at least annually. For the floodwater retarding structures and the grade stabilization structures items of inspection will include, but not be limited to, the condition of the principal spillway and its appurtenances, the emergency spillway, the earth fill, the vegetative cover of the earth fill and emergency spillway, and the fences and gates installed as part of the structures. For structures for streambank protection, items of inspection will include, but not be limited to, the condition of the posts and wire fences, the density of woody vegetation, and the degree of streambank erosion. The items of inspection are those most likely to require maintenance.

The Soil Conservation Service, through the Duck Creek Soil Conservation District will participate in operation and maintenance only to the extent of furnishing technical assistance to aid in inspections and furnishing technical guidance and information necessary for the operation and maintenance program.

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

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

The sponsoring local organizations fully understand their obligations for maintenance and will execute specific maintenance agreements prior to the issuance of invitation to bid on the construction of the structural measures included in this work plan.

The necessary maintenance work will be accomplished either by contract, force account, or equipment owned by the sponsoring organizations.

TABLE 1 - ESTIMATED PROJECT INSTALLATION COST

Duck Creek Watershed, Texas

Installation Cost Items	Unit	No. to be Applied Non-Federal Land 2/	Estimated Cost (Dollars) 1/ Public Law: 566 Funds	Other Funds	Total
LAND TREATMENT					
Soil Conservation Service					
Cropland	Acre	11,700	-	925,200	925,200
Pastureland	Acre	1,950	-	29,340	29,340
Rangeland	Acre	13,000	-	303,477	303,477
Technical Assistance			-	40,471	40,471
TOTAL LAND TREATMENT			-	1,298,488	1,298,488
STRUCTURAL MEASURES					
Soil Conservation Service					
Floodwater Retarding Structures	No.	12	1,323,772	-	1,323,772
Grade Stabilization Structures	No.	5	113,863	-	113,863
Streambank Protection	Foot	7,050	31,020	-	31,020
Subtotal - Construction			1,468,655	-	1,468,655
Installation Services					
Engineering Services			213,381	-	213,381
Other			128,171	-	128,171
Subtotal - Installation Services			341,552	-	341,552
Other Costs					
Land, Easements, and Rights-of-Way			-	138,989	138,989
Administration of Contracts			-	9,000	9,000
Water Rights			-	1,200	1,200
Subtotal - Other			-	149,189	149,189
TOTAL STRUCTURAL MEASURES			1,810,207	149,189	1,959,396
TOTAL PROJECT			1,810,207	1,447,677	3,257,884

1/ Price Base: 1964

2/ For Land Treatment: Acres to be treated during project installation period.

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TABLE 1A - STATUS OF WATERSHED WORKS OF IMPROVEMENT
(at time of work plan preparation)

Duck Creek Watershed, Texas

Measures	Unit	Number Applied To Date	Total Cost (Dollars) 1/
LAND TREATMENT			
Conservation Cropping System	Acre	41,310	0
Grasses and Legumes in Rotation	Acre	800	52,800
Cover and Gree Manure Crops	Acre	120	7,920
Mulching	Acre	1,535	63,323
Fertilizing	Acre	3,620	99,550
Crop Residue Use	Acre	40,330	388,176
Contour Farming	Acre	34,081	93,720
Grassed Waterway	Acre	19	950
Terrace	Feet	4,356,000	130,680
Diversion	Feet	149,740	14,974
Irrigation Water Management	Acre	1,691	46,500
Irrigation Land Leveling	Acre	310	15,500
Irrigation System, Surface	No.	17	3,400
Irrigation System, Sprinkler	No.	15	22,500
Irrigation Pipeline	Feet	127,500	159,375
Pasture Proper Use	Acre	1,255	6,903
Pasture and Hayland Planting	Acre	1,255	8,785
Range Proper Use	Acre	48,600	133,650
Range Deferred Grazing	Acre	36,800	101,155
Range Seeding	Acre	300	1,500
Brush and Weed Control	Acre	9,750	39,000
Farm Pond	No.	150	115,500
TOTAL			1,505,861

1/ Price Base: 1964

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TABLE 2 - ESTIMATED STRUCTURE COST DISTRIBUTION - DUCK CREEK WATERSHED

(Dollars) 1/

Structure Site Number or Name	Installation Cost - Public Law 566 Funds: Construction	Installation Services: Engineering	Installation Services: Other	Total Public Law 566	Installation Cost - Other Funds: Construction	Installation Services: Engineering	Installation Services: Other	Adm. of Contracts	Land, Easements, and R/W 2/	Water Rights	Total Other	Total Installation Cost
Floodwater Retarding Structures												
1	254,288	25,429	21,315	301,032	-	-	-	500	21,530	600	22,630	323,662
2	61,833	11,130	5,560	78,523	-	-	-	500	3,665	-	4,165	82,688
3	114,921	14,940	9,895	139,756	-	-	-	500	8,486	-	8,986	148,742
4	54,670	9,841	4,916	69,427	-	-	-	500	2,438	-	2,938	72,365
5	149,565	16,452	12,650	178,667	-	-	-	500	13,940	-	14,440	193,107
					(5,008)	(551)	(424)	-	(605)	(600)	(7,188)	(7,188)
6	71,956	10,793	6,306	89,055	-	-	-	500	3,893	-	4,393	93,448
7	185.785	20,436	15,714	221,935	-	-	-	500	10,518	-	11,018	232,953
8	140,855	18,311	12,129	171,295	-	-	-	500	28,247	600	29,347	200,642
9	62,972	9,446	5,518	77,936	-	-	-	500	7,822	-	8,322	86,258
10	76,105	11,416	6,669	94,190	-	-	-	500	9,525	-	10,025	104,215
11	55,223	9,940	4,965	70,128	-	-	-	500	11,782	-	12,282	82,410
12	95,599	14,340	8,377	118,316	-	-	-	500	12,640	-	13,140	131,456
Subtotal	1,323,772	172,474	114,014	1,610,260	-	-	-	6,000	134,486	1,200	141,686	1,751,946
Grade Stabilization Structures												
CA-1	28,251	7,063	2,691	38,005	-	-	-	500	760	-	1,260	39,265
CA-2	24,011	6,003	2,287	32,301	-	-	-	500	595	-	1,095	33,396
CA-3	17,009	5,443	1,711	24,163	-	-	-	500	403	-	903	25,066
CA-4	25,673	6,418	2,445	34,536	-	-	-	500	687	-	1,187	35,723
CA-5	18,919	6,054	1,903	26,876	-	-	-	500	558	-	1,058	27,934
Subtotal	113,863	30,981	11,037	155,881	-	-	-	2,500	3,003	-	5,503	161,384
Streambank Protection Structures												
101	7,676	2,456	772	10,904	-	-	-	144	407	-	551	11,455
102	4,264	1,364	429	6,057	-	-	-	80	226	-	306	6,363
103	3,411	1,092	343	4,846	-	-	-	64	180	-	244	5,090
104	3,980	1,274	400	5,654	-	-	-	75	210	-	285	5,939
105	3,127	1,001	315	4,443	-	-	-	59	166	-	225	4,668
106	2,842	909	286	4,037	-	-	-	53	151	-	204	4,241
107	5,720	1,830	575	8,125	-	-	-	25	160	-	185	8,310
Subtotal	31,020	9,926	3,120	44,066	-	-	-	500	1,500	-	2,000	46,066
GRAND TOTAL	1,468,655	213,381	128,171	1,810,207	-	-	-	9,000	138,989	1,200	149,189	1,959,396

1/ Price Base: 1964 2/ Includes value for legal fees.

NOTE: Data in parenthesis are non-project costs allocated to irrigation storage in floodwater retarding structure No. 5.

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TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES

Duck Creek Watershed, Texas

Item	Unit	Structure Number 1	2	3
Drainage Area	Sq.Mi.	20.49	4.34	7.26
Storage Capacity				
Sediment Pool (200 ac.ft. limit)	Ac.Ft.	-	-	200
Sediment Pool or Reserve (Below Riser-50 yr.)	Ac.Ft.	634 2/	109	13
Sediment Reserve (Above Riser-100 yr.)	Ac.Ft.	994	174	337
Sediment in Detention Pool	Ac.Ft.	678	120	232
Floodwater Detention	Ac.Ft.	4,994	495	1,080
Total	Ac.Ft.	7,300	898	1,862
Surface Area				
Sediment Pool (50 yr. or 200 ac.ft. limit)	Acre	77	19	39
Sediment Reserve Pool (100 yr.)	Acre	144	35	77
Floodwater Detention Pool	Acre	424	76	147
Volume of Fill	Cu.Yd.	576,730	117,990	228,730
Elevation Top of Dam	Foot	2564.7	2554.4	2517.0
Maximum Height of Dam 4/	Foot	52	36	32
Emergency Spillway				
Crest Elevation	Foot	2558.1	2550.0	2512.0
Bottom Width	Foot	600	200	160
Type	xxx	Veg.	Veg.	Veg.
Percent Chance of Use 5/	xxx	0.8	4.0	2.7
Average Curve No. - Condition II	xxx	75	75	75
Emergency Spillway Hydrograph				
Storm Rainfall (6-hour) 6/	Inch	7.87	5.60	5.60
Storm Runoff	Inch	4.93	2.94	2.94
Velocity of Flow (V_c) 7/	Ft./Sec.	4.3	4.2	3.3
Discharge Rate 7/	C.F.S.	1,530	778	184
Maximum Water Surface Elevation 7/	Foot	2559.5	2551.7	2512.9
Freeboard Hydrograph				
Storm Rainfall (6-hour) 8/	Inch	16.59	10.90	10.90
Storm Runoff	Inch	13.16	7.73	7.73
Velocity of Flow (V_c) 7/	Ft./Sec.	11.1	8.9	9.7
Discharge Rate 7/	C.F.S.	25,950	4,478	4,700
Maximum Water Surface Elevation 7/	Foot	2564.7	2554.4	2517.0
Principal Spillway				
Capacity - Low Stage	C.F.S.	102	22	36
Capacity Equivalents				
Sediment Volume	Inch	2.11	1.74	2.02
Irrigation Volume	Inch	-	-	-
Detention Volume	Inch	4.57	2.14	2.79
Spillway Storage	Inch	2.92	1.64	2.09
Class of Structure	xxx	B	A	A

(Footnotes on last page of Table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Duck Creek Watershed, Texas

Item	Unit	Structure Number 4	5	6
Drainage Area	Sq.Mi.	1.93	21.85	2.28
Storage Capacity				
Sediment Pool (200 ac.ft. limit)	Ac.Ft.	-	-	-
Sediment Pool or Reserve (Below Riser-50 yr.)	Ac.Ft.	73	-	61
Sediment Reserve (Above Riser-100 yr.)	Ac.Ft.	93	2,249 3/	76
Sediment in Detention Pool	Ac.Ft.	62	746	50
Floodwater Detention	Ac.Ft.	302	3,111	394
Total	Ac.Ft.	530	6,106	581
Surface Area				
Sediment Pool (50 yr. or 200 ac.ft. limit)	Acre	12	-	12
Sediment Reserve Pool (100 yr.)	Acre	22	148	19
Floodwater Detention Pool	Acre	51	318	61
Volume of Fill	Cu.Yd.	84,650	340,110	108,020
Elevation Top of Dam	Foot	2532.3	2532.7	2583.4
Maximum Height of Dam 4/	Foot	28	70	28
Emergency Spillway				
Crest Elevation	Foot	2528.9	2527.6	2580.1
Bottom Width	Foot	100	400	150
Type	xxx	Veg.	Veg.	Veg.
Percent Chance of Use 5/	xxx	2.6	2.5	2.7
Average Curve No. - Condition II	xxx	75	75	78
Emergency Spillway Hydrograph				
Storm Rainfall (6-hour) 6/	Inch	5.60	5.28	5.60
Storm Runoff	Inch	2.94	2.67	3.24
Velocity of Flow (V_c) 7/	Ft./Sec.	2.0	4.0	3.3
Discharge Rate 7/	C.F.S.	20	191	139
Maximum Water Surface Elevation 7/	Foot	2529.2	2528.1	2580.9
Freeboard Hydrograph				
Storm Rainfall (6-hour) 8/	Inch	10.90	10.27	10.90
Storm Runoff	Inch	7.73	7.12	8.13
Velocity of Flow (V_c) 7/	Ft./Sec.	8.0	9.8	5.0
Discharge Rate 7/	C.F.S.	1,570	12,291	2,064
Maximum Water Surface Elevation 7/	Foot	2532.3	2532.7	2583.4
Principal Spillway				
Capacity - Low Stage	C.F.S.	10	109	11
Capacity Equivalents				
Sediment Volume	Inch	2.21	2.40	1.54
Irrigation Volume	Inch	-	.17	-
Detention Volume	Inch	2.94	2.67	3.24
Spillway Storage	Inch	1.91	1.52	1.82
Class of Structure	xxx	A	A	A

(Footnotes on last page of Table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Duck Creek Watershed, Texas

Item	Unit	Structure Number 7	8	9
Drainage Area	Sq.Mi.	11.50	11.06 1/	1.49
Storage Capacity				
Sediment Pool (200 ac.ft. limit)	Ac.Ft.	200	-	-
Sediment Pool or Reserve (Below Riser-50 yr.)	Ac.Ft.	285	437 2/	70
Sediment Reserve (Above Riser-100 yr.)	Ac.Ft.	570	348	89
Sediment in Detention Pool	Ac.Ft.	405	224	61
Floodwater Detention	Ac.Ft.	2,147	2,006	258
Total	Ac.Ft.	3,607	3,015	478
Surface Area				
Sediment Pool (50 yr. or 200 ac.ft. limit)	Acre	33	88	21
Sediment Reserve Pool (100 yr.)	Acre	104	122	30
Floodwater Detention Pool	Acre	215	337	69
Volume of Fill	Cu.Yd.	328,510	263,690	129,560
Elevation Top of Dam	Foot	2565.7	2451.1	2439.4
Maximum Height of Dam 4/	Foot	44	39	22
Emergency Spillway				
Crest Elevation	Foot	2560.8	2447.1	2436.7
Bottom Width	Foot	300	400	100
Type	xxx	Veg.	Veg.	Veg.
Percent Chance of Use 5/	xxx	2.2	1.6	3.0
Average Curve No. - Condition II	xxx	80	76	78
Emergency Spillway Hydrograph				
Storm Rainfall - (6-hour) 6/	Inch	5.54	5.21	5.60
Storm Runoff	Inch	3.38	2.71	3.24
Velocity of Flow (V_c) 7/	Ft./Sec.	3.6	0	2.3
Discharge Rate 7/	C.F.S.	442	0	40
Maximum Water Surface Elevation 7/	Foot	2561.7	-	2437.2
Freeboard Hydrograph				
Storm Rainfall (6-hour) 8/	Inch	10.79	10.14	10.90
Storm Runoff	Inch	8.28	7.14	8.13
Velocity of Flow (V_c) 7/	Ft./Sec.	9.4	8.3	6.7
Discharge Rate 7/	C.F.S.	7,842	7,316	962
Maximum Water Surface Elevation 7/	Foot	2565.7	2451.1	2439.4
Principal Spillway				
Capacity - Low Stage	C.F.S.	58	124	8
Capacity Equivalents				
Sediment Volume	Inch	2.38	1.71	2.77
Irrigation Volume	Inch	-	-	-
Detention Volume	Inch	3.50	3.40	3.24
Spillway Storage	Inch	1.80	2.54	3.81
Class of Structure	xxx	A	A	A

(Footnotes on last page of Table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Duck Creek Watershed, Texas

Item	Unit	Structure Number 10	11	12
Drainage Area	Sq.Mi.	3.04	6.80	16.36
Storage Capacity				
Sediment Pool (200 ac.ft. limit)	Ac.Ft.	-	-	-
Sediment Pool or Reserve (Below Riser-50 yr.)	Ac.Ft.	88	76	140
Sediment Reserve (Above Riser-100 yr.)	Ac.Ft.	108	94	183
Sediment in Detention Pool	Ac.Ft.	71	51	78
Floodwater Detention	Ac.Ft.	488	1,016	2,017
Total	Ac.Ft.	755	1,237	2,418
Surface Area				
Sediment Pool (50 yr. or 200 ac.ft. limit)	Acre	19	33	33
Sediment Reserve Pool (100 yr.)	Acre	41	52	67
Floodwater Detention Pool	Acre	101	243	319
Volume of Fill	Cu.Yd.	139,100	111,660	153,980
Elevation Top of Dam	Foot	2393.9	2285.1	2243.0
Maximum Height of Dam 4/	Foot	25	19	34
Emergency Spillway				
Crest Elevation	Foot	2390.9	2281.0	2238.0
Bottom Width	Foot	200	120	400
Type	xxx	Veg.	Veg.	Veg.
Percent Chance of Use 5/	xxx	3.0	2.9	4.0
Average Curve No. - Condition II	xxx	78	79	79
Emergency Spillway Hydrograph				
Storm Rainfall (6-hour) 6/	Inch	5.60	5.60	5.41
Storm Runoff	Inch	3.24	3.32	3.16
Velocity of Flow (Vc) 7/	Ft./Sec.	3.3	4.0	5.2
Discharge Rate 7/	C.F.S.	215	241	1,818
Maximum Water Surface Elevation 7/	Foot	2391.5	2282.2	2239.8
Freeboard Hydrograph				
Storm Rainfall (6-hour) 8/	Inch	10.90	10.90	10.53
Storm Runoff	Inch	8.13	8.25	7.90
Velocity of Flow (Vc) 7/	Ft./Sec.	7.5	8.5	9.5
Discharge Rate 7/	C.F.S.	2,615	2,391	11,068
Maximum Water Surface Elevation 7/	Foot	2393.9	2285.1	2243.0
Principal Spillway				
Capacity - Low Stage	C.F.S.	15	34	82
Capacity Equivalents				
Sediment Volume	Inch	1.65	0.61	0.46
Irrigation Volume	Inch	-	-	-
Detention Volume	Inch	3.01	2.80	2.31
Spillway Storage	Inch	2.12	3.72	2.30
Class of Structure	xxx	A	A	A

(Footnotes on last page of Table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES - Continued

Duck Creek Watershed, Texas

Item	Unit	Total
Drainage Area	Sq.Mi.	108.40
Storage Capacity		
Sediment Pool (200 ac.ft. limit)	Ac.Ft.	400
Sediment Pool or Reserve (Below Riser-50 yr.)	Ac.Ft.	1,986
Sediment Reserve (Above Riser-100 yr.)	Ac.Ft.	5,315 9/
Sediment in Detention Pool	Ac.Ft.	2,778
Floodwater Detention	Ac.Ft.	18,308
Total	Ac.Ft.	28,787
Surface Area		
Sediment Pool (50 yr. or 200 ac.ft. limit)	Acre	396
Sediment Reserve Pool (100 yr.)	Acre	861
Floodwater Detention Pool	Acre	2,361
Volume of Fill	Cu.Yd.	2,582,730
Elevation Top of Dam	Foot	xxx
Maximum Height of Dam 4/	Foot	xxx
Emergency Spillway		
Crest Elevation	Foot	xxx
Bottom Width	Foot	xxx
Type	xxx	xxx
Percent Chance of Use 5/	xxx	xxx
Average Curve No. - Condition II	xxx	xxx
Emergency Spillway Hydrograph		
Storm Rainfall (6-hour) 6/	Inch	xxx
Storm Runoff	Inch	xxx
Velocity of Flow (V_c) 7/	Ft./Sec.	xxx
Discharge Rate 7/	C.F.S.	xxx
Maximum Water Surface Elevation 7/	Foot	xxx
Freeboard Hydrograph		
Storm Rainfall (6-hour) 8/	Inch	xxx
Storm Runoff	Inch	xxx
Velocity of Flow (V_c) 7/	Ft./Sec.	xxx
Discharge Rate 7/	C.F.S.	xxx
Maximum Water Surface Elevation 7/	Foot	xxx
Principal Spillway		
Capacity - Low Stage	C.F.S.	xxx
Capacity Equivalents		
Sediment Volume	Inch	xxx
Irrigation Volume	Inch	xxx
Detention Volume	Inch	xxx
Spillway Storage	Inch	xxx
Class of Structure	xxx	xxx

(Footnotes on last page of Table 3.)

TABLE 3 - STRUCTURE DATA - FLOODWATER RETARDING STRUCTURES -Continued

Duck Creek Watershed, Texas

1/ Exclusive of area controlled by other structures. The entire area considered in the emergency spillway design.

2/ Permit to be obtained to store to the 50-year sediment.

3/ Permit to be obtained to store to the 100-year sediment plus 198 acre-feet for irrigation below riser.

4/ Height above valley floor.

5/ Based on regional analysis of gaged runoff.

6/ From Plate 2-a1 for Class "A", Plate 2-b1 for Class "B".

7/ Maximum during passage of hydrograph.

8/ From Plate 2-a2 for Class "A", Plate 2-b2 for Class "B".

9/ Includes 198 acre-feet for irrigation.

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TABLE 3A - STRUCTURE DATA

GRADE STABILIZATION STRUCTURES

Duck Creek Watershed, Texas

Item	Unit	Structure Number CA-1	CA-2	CA-3	CA-4	CA-5	Total
Drainage Area	Sq.Mi.	.94	.57	.27	.48	.48	2.74
Drainage Area	Acres	600	365	173	307	307	1,752
Storage Capacity							
Sediment	Ac.Ft.	26	36	6	32	11	111
Sediment (Above Riser)	Ac.Ft.	11	7	3	6	4	31
Detention Storage	Ac.Ft.	58	36	16	23	27	160
Total	Ac.Ft.	95	79	25	61	42	302
Height of Emergency Spillway Above Valley Floor	Foot	30	31	23	35	24	xxx
Volume of Fill	Cu.Yd.	41,780	32,730	11,300	32,370	18,390	136,570
Average Curve No. - Condition II	xxx	75	75	75	75	75	xxx
Principal Spillway Discharge Rate	C.F.S.	117	73	37	80	68	xxx
Emergency Spillway							
Type	xxx	Veg.	Veg.	Veg.	Veg.	Veg.	xxx
Percent Chance of Use	xxx	2.0	2.0	2.0	2.0	2.0	xxx
Storm Rainfall	Inch	4.19	4.00	4.10	4.19	4.09	xxx
Storm Runoff	Inch	1.82	1.67	1.74	1.82	1.73	xxx
Discharge Rate	C.F.S.	270	15	84	205	154	xxx
Bottom Width	Foot	30	30	30	30	30	xxx
Capacity Equivalents							
Sediment Volume	Inch	0.74	1.42	0.64	1.48	0.58	xxx
Detention Volume	Inch	1.13	1.18	1.10	0.90	1.05	xxx

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TABLE 3B - STRUCTURE DATA - STREAMBANK PROTECTION

Duck Creek Watershed, Texas

Stream Name	Structural Site Number	Length of Streambank Protection (feet)	Station Numbering: Station (100 feet)	Station Numbering: Station (100 feet)	Bank Designation 1/	Average Height of Bank (feet)
Duck Creek	101	1,350	1125+15	1138+65	Right	13
	102	750	1115+65	1123+15	Left	15
	103	600	991+90	997+90	Left	7
	104	700	780+40	787+40	Right	10
	105	550	572+35	577+85	Right	8
Cottonwood Creek	106	500	160+35	165+35	Right	15
Dockum Creek	107	2,600 2/	857+70	880+10	2/	10

Total Length = 7,050 feet

1/ Downstream view.

2/ Includes portions of both banks.

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TABLE 4 - ANNUAL COST

Duck Creek Watershed, Texas

(Dollars)

Evaluation Unit	Amortization of Installation Cost 1/	Operation and Maintenance Cost 2/	Total
Floodwater Retarding Structures Nos. 1 through 12, Grade Stabilization Structures Nos. CA-1 through CA-5, and Streambank Protection Structures Nos. 101 through 107	64,190	2,664 3/	66,854
TOTAL	64,190	2,664 3/	66,854

1/ Price Base: 1964 prices amortized for 100 years at 3-1/8 percent.

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

3/ Includes replacement cost.

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TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE REDUCTION BENEFITS

Duck Creek Watershed, Texas

(Dollars) 1/

Item	Estimated Average Annual Damage: Without Project	With Project	Damage Reduction Benefits
Floodwater			
Crop and Pasture	117,569	48,451	69,118
Other Agricultural	26,692	7,497	19,195
Nonagricultural			
Road and Bridge	18,901	4,060	14,841
Subtotal	163,162	60,008	103,154
Sediment			
Overbank Deposition	70,596	7,945	62,651
Erosion			
Streambank	2,695	457	2,238
Flood Plain Scour	5,275	1,229	4,046
Indirect	24,173	6,964	17,209
TOTAL	265,901	76,603	189,298

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

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TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Duck Creek Watershed, Texas

(Dollars)

Measures	AVERAGE ANNUAL BENEFITS 1/					Average Annual Cost 2/	Benefit Cost Ratio
	Flood Prevention						
	Damage Reduction	Incidental Recreation	Incidental Irrigation	Secondary	Total		
Floodwater Retarding Structures Nos. 1 through 12, Grade Stabilization Structures Nos. CA-1 through CA-5, and Streambank Protection Structures Nos. 101 through 107	170,691	1,096	1,508	15,609	188,904	66,854	2.8:1
GRAND TOTAL 3/	170,691	1,096	1,508	15,609	188,904	66,854	2.8:1

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

2/ From Table 4.

3/ In addition, it is estimated that land treatment measures will provide flood damage reduction benefits of $18,607 annually.

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INVESTIGATIONS AND ANALYSES

Land Use and Treatment

The status of land treatment for the watershed was developed by the Duck Creek Soil Conservation District assisted by personnel from the Soil Conservation Service at Spur. Conservation needs data were compiled from existing conservation plans within the watershed and expanded to represent the conservation needs of the entire watershed. The quantity of each land treatment practice, or combination of practices, necessary for essential conservation treatment was estimated for each land use by capability class. Acres, by land use, to be treated during the 5-year project installation period were estimated (table 1). The hydraulic, hydrologic, sedimentation, and economic investigations provided data as to the effects of land treatment measures in terms of the reduction of flood damage. Although measurable benefits would result from application of the planned land treatment measures, it was apparent that other flood prevention measures would be required to attain the degree of watershed protection and flood damage reduction desired by the local people.

Engineering Investigations

A study was made of the watershed to determine where structural measures could be used and, if by including them in the plan, the project objectives for flood prevention could be attained. The procedure used in making that determination was as follows:

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

2. A study of aerial photographs supplemented by field examination indicated the limits of flood plain subject to flood damage. All probable sites for floodwater retarding structures were located on a map of the watershed. By making a stereoscopic study of aerial photographs, supplemented by field examination, it was possible to eliminate those sites which did not have sufficient available storage capacity.

3. The watershed map, showing all possible site locations which might be used to develop a system of structural measures that would meet project objectives, was submitted to the sponsoring local organizations. The sponsors provided data on ownership of land apparently involved in each site and cost estimates on necessary easements.

4. Based on apparent physical, economic, and easement feasibility, the sponsoring local organizations and the Soil Conservation Service agreed that 15 possible site locations for floodwater retarding structures would be investigated. Two of these sites were to be considered for extra storage of water for irrigation. In addition to the 15 possible site locations for floodwater detention structures, it was

agreed that 7 critical sediment source areas would be considered for treatment. It was also agreed that several miles of channel improvement and streambank protection would be investigated.

Reservoir operation studies to determine the adequacy of water yield for irrigation were made for Sites Nos. 1 and 5, as requested by sponsoring local organizations. These studies indicated sufficient water yield to irrigate the desired acreage.

It was necessary to plan two floodwater retarding structures, Nos. 6 and 7, in series with Site No. 8. It is more economical and feasible to get the required storage for floodwater detention with 3 structures than with one because of added benefits below Site Nos. 6 and 7 and involvement of obstacles at Site No. 8.

Detailed investigations were made of two critical sediment source areas above Site No. 1 and three areas above Site No. 5. Special treatment was planned for these areas.

Studies in connection with streambank erosion indicated that structural measures would be required and were economically justified to protect 7,050 feet of the most seriously eroding areas of bank erosion. A structure for streambank protection is illustrated by figure 4.

Approximately 14 miles of stream channel investigated for possible improvement were found to be infeasible at the present time.

5. Each site location was classified for limiting design criteria according to the damage that would result from a sudden major breach of the embankment. Breaching studies were made for Site No. 1 and Site No. 2 above Highway No. 82. These studies indicated that Site No. 1 should be classified as "b" because traffic would be disrupted if a sudden breach were to occur. A sudden breach of the dam at Site No. 2 would not cause undue hazard to life or property.

   Site No. 1 was classified as "b" and all other structures are classified as "a".

6. A topographic map of each site was developed to cover the pools, dam, and emergency spillway areas. These maps and related surveys provided necessary information to determine if the required irrigation, sediment, and floodwater detention storage capacity could be obtained, the limit of the pool areas, estimated installation costs, and the most economical design for each structure.

7. The sediment and floodwater storage, structure classification, and principal and emergency spillway layout and design meet or exceed criteria outlined in Engineering Memorandum SCS-27 and Texas State Manual Supplement 2441.

   Multiple routings of freeboard hydrographs were made for all sites to determine the spillway proportion and height of dam which would result in the most economical and feasible design of the structures. Plans of a floodwater retarding structure, typical of these planned for this watershed, are illustrated by figures 3 and 3A.

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

   A detailed investigation was also made to see what effect floodwater retarding structures would have on roads, highways, and utility lines above the sites.

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

10. Damages resulting from floodwater, sediment, and flood plain erosion were determined from damage schedules, surveys of sample areas, and flood routings under without project conditions. Reductions in these damages resulting from the proposed works of improvements were estimated on the basis of reduction of sediment yields and reduction of peak discharges as determined by flood routings under future conditions for which it was assumed that the proposed works of improvements had been installed.

    Benefits so determined were allocated to measures or groups of interrelated measures on the basis of the contribution each measure had on the reduction of damages. In this manner, it was determined that structural measures for flood prevention could be economically justified.

    By further analysis those individual and interrelated structural measures which had favorable benefit to cost ratios were determined. Alternate sites, with and without channel improvement, were investigated until the most

economical and feasible system of structural measures was developed which would provide the degree of protection desired by the sponsoring local organizations.

The system consisted of 12 interrelated floodwater retarding structures, 5 grade stabilization structures for critical area treatment, and 7 structures for 7,050 feet of streambank protection necessary to provide the desired level of flood damage reduction.

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

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

Hydraulic and Hydrologic Investigations

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

1. Basic meteorologic and hydrologic data were tabulated from Climatological Bulletins, U. S. Weather Bureau, U. S. Geological Survey Water Supply Papers, and local records. These data were analyzed to determine average precipitation depth-duration relationships, seasonal distribution of precipation, and frequency of occurrence of meteorological events.

2. Engineering surveys were made of valley cross sections, high water marks, bridges, and other data pertinent in determining flood damages. The cross sections were selected to represent the stream hydraulics and flood plain area. Evaluation reaches were delineated after joint study with the economist and geologist.

   Partial valley cross sections for planning stream channel improvement were surveyed at approximately 1,000 foot intervals on Dockum and Salt Creeks in the reaches where channel improvement was studied.

3. The before-project hydrologic conditions of the watershed were determined on the basis of cover conditions, land treatment, soil groups, and crop distribution. The II-Curve number of 76 for the hydrologic soil-cover complex was determined from a 27 percent sample of the watershed of Duck Creek and its tributaries.

The after-project conditions were determined by analyzing the results of the land treatment that would be applied during the installation period. This study revealed that a II Condition Curve number of 75 is applicable.

4. Cross section rating curves for Duck Creek and Dockum Creek were developed from field survey data collected in 2, above, by solving water surface profiles for various discharges. Computations of the water surface profiles were made by the use of the IBM 650 Computer.

5. Runoff-peak discharge relationships were determined by flood routing the runoff from the 24-hour 10-year frequency rainfall as selected from Technical Paper No. 40, U. S. Weather Bureau. The storage-indication method of routing, modified by the use of a variable routing interval, was used. Initial hydrographs for routing were developed by means of Common's distribution graph. The peak discharge for each subwatershed was determined from the volume of runoff produced by a storm of duration equal to the time of concentration. Peak discharges for other frequency storms used in the evaluation were directly proportional to the volume of runoff.

   Peak discharges under project conditions were determined in a similar manner by flood routing the runoff from the uncontrolled areas. The 24-hour 100-year frequency rainfall was routed through the watershed with all planned structures in place. This was used to evaluate the effect of structure measures on the 50 and 100-year frequency rainfall. A maximum release rate of 5.0 c.s.m. was used for all structures.

6. Stage-area inundated curves were developed from field survey data for each portion of the valley represented by a cross section. Area inundated data by incremental depths of flooding were developed for each evaluation reach by routing volumes of runoff for selected frequencies using the peak discharge-volume relationships.

7. Determinations were made of the area that would have been inundated by storms of selected frequencies under each of the following conditions:

   a. The without-project condition using the before-project soil-cover complex number.

   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 stream channel improvement.

8. The runoff from the 100-year frequency 24-hour storm was routed to determine the maximum flood plain area that would be used in the computations of damages and benefits.

Sedimentation Investigations

Sedimentation investigations were made in accordance with procedures as outlined in State Technical Memorandum WS TS-25, Sedimentation Investigations in Work Plan Development, August 1959, Fort Worth, Texas; Technical Release No. 17, "Geologic Investigations for Watershed Planning", March 1961; and Technical Release No. 12, "Procedures for Computing Sediment Requirements for Retarding Reservoirs", September 1959.

Sediment Source Studies

Sediment source studies to determine the 100-year sediment storage requirements were made in the drainage areas of the 12 planned floodwater retarding structures. Detailed investigations were made in the drainage areas of six of the planned structures. Estimates of the sediment production rates for the other six structures were based on data gathered in the detailed investigations of similar drainage areas.

The six detailed investigations and computations included:

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

2. Measuring lengths, widths, and depths, and studying old aerial photographs to estimate rates of annual lateral erosion of all gullies and stream channels affected by erosion.

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

4. Computing annual gross erosion by sources (sheet, gully, and streambank). The soil loss equation by Musgrave was used in sheet erosion computation.

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

1. Mapping the land use.

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

3. Computing annual gross erosion based on erosion rates of the detailed area.

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

Sediment storage requirements for planned structures were determined by adjusting average annual total erosion for expected sediment delivery ratios and trap efficiency. The ratio of sediment volume submerged in pools to soil in place was based on volume weights of 62 to 84 pounds per cubic foot for submerged sediment and 87 to 94 pounds per cubic foot for soil in place.

The allocation of sediment to the structure pools was based on a range of 25 to 40 percent deposition in the sediment pools below the riser, 35 to 45 percent in the sediment reserve pools above the riser, and 25 to 30 percent in the detention pools.

Critical Sediment Source Studies

Field examinations of gullies and streams were made to determine conditions at headcuts, overfalls, and banks. Special note was taken of active head-cutting and lateral erosion, the type of land being eroded, the nature of sediment movement and deposition downstream, and the degree of natural stabilization caused by re-vegetation. Comparisons of older and new aerial photographs were made to estimate rates of gully and stream channel en-largement.

The Caprock Escarpment contains numerous large, rapidly eroding gullies. Five of these gullied areas were selected as critical sediment source areas to be treated. Selection was made on the basis of present sediment pro-duction rates and their potential to continue at or greater than the present rate. Those gullies which have advanced to or near the upper limits of their drainage areas were not selected for treatment.

There are seven segments of rapidly eroding streambanks causing severe loss of valuable land and contributing excessive amounts of sediment to stream channels and flood plains. These segments were designated as critical areas to be treated.

Flood Plain Sediment and Scour Damages

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

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

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

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

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

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

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

7. Average annual sediment yield from each source (sheet erosion, gully erosion, streambank erosion, streambed erosion, and flood plain scour) was estimated from detailed sediment source studies and scour damage investigations. Sediment yields to evaluation reaches were computed for without project conditions, with land treatment measures applied, and with the combined program of land treatment and structural measures installed.

   The reduction in sediment yield was adjusted to reflect the relative importance of each sediment source as a contributor of damage. The reduction of monetary damage from overbank deposition was based on the reduction of area inundated by floodwater and reduction in damaging sediment yield.

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

Channel Stability Studies

Channel stability studies were made for Duck, Dockum, and Cottonwood Creeks. Fifteen borings with core drilling equipment and eight hand auger borings were made at selected locations to study the nature of bedload and soil materials. Mechanical analyses and tests to determine Atterberg limits, soluble salt content, and disperison were made of 16 samples of representative horizons.

The bedload is primarily fine to medium grained sands classified as SP in accordance with the Unified Soil Classification System. This SP is underlain by clayey sands, silty sands, and sandy clays at depths ranging from one to seven feet. Based on the median grain size of non-cohesive bedload materials and plasticity indices of cohesive materials, the application of critical tractive force values indicated bedload movement in evaluation

reaches 2 through 5, reach 9, and upstream from VS-D-12 in evaluation reach 8 (figure 1). Bedload movement would also occur under project conditions in these reaches.

The Schoklitch bedload transport equation was used to estimate the rate of bedload movement within each reach. Comparison of estimates of bedload movement under present conditions with that under project conditions indicated that installation of the project would have a negligable effect in the volume of bedload movement. After comparing estimated incoming bedload with bedload transport capacity, it was indicated that a relatively stable condition will exist under project conditions. The study indicated very slight degradation in the upper reaches and very slight aggradation in the lower reaches.

Geologic Investigations

Preliminary geologic investigations were made at each of the floodwater retarding structure sites to obtain information on the nature and extent of embankment and foundation materials, emergency spillway excavation, emergency spillway stability, and possible problems that might be encountered during construction. These investigations included surface observations of valley slopes, alluvium, channel banks, exposed geologic formations, and hand auger borings. The findings of these investigations were used in making cost estimates of structures and to assure that the sites selected are feasible for construction.

Description of Problems

Formations of the Permian and Triassic systems crop out at dam sites. The Permian system is represented by beds of the Peacock formation of the Double Mountain group. These beds, as seen at structure sites, consist of red and greenish gray shales and siltstones with occasional thin beds of fine grained sandstone. Some joints, fractures, bedding planes, and small faults are filled with gypsum. Thick gypsum beds occur in the lower section of the Peacock formation, but not in the vicinity of floodwater retarding structure sites.

Beds of the Triassic system lie unconformably on the eroded surface of the Peacock formation. The Triassic system is represented at structure sites by two formations of the Dockum group. The Santa Rosa formation is of more importance at sites and consists of fine to medium grained, cross-bedded sandstone and lenticular beds of quartzose conglomerate. The Tecovas formation, consisting of shales, clays, and dense slightly indurated sands, normally underlies the Santa Rosa formation, but it is either very thin or absent at most structure sites.

Site Nos. 1, 3, 5, and 8 are located at the Permian-Triassic contact. Generally, the abutments are composed of sandstones and conglomerates of the Santa Rosa formation, and the flood plains are underlain by shales, siltstones, and thin-bedded sandstones of the Peacock formation.

Site Nos. 2, 4, 6, and 7 are located entirely on the outcrop of the Dockum group. Interbedded sandstones, conglomerates, shales, and dense sands

occur on abutments and underlie flood plain alluvium.

Site Nos. 9, 10, 11, and 12 are located entirely on the outcrop of interbedded shales, siltstones, and thin sandstone beds of the Peacock formation.

Flood plain alluvium consists mostly of beds and lenses of sandy clay, siltly clay, clayey sand, and silty sand. These soils, as classified in accordance with the Unified Soil Classification System, are CL, SC, and SM. There are some beds and lenses of sand and gravel (SP and GP). It is anticipated that deep cutoff trenchs, extending to bedrock through pervious lenses in the alluvium will be needed at Site Nos. 1, 3, 5, and 7. At Site No. 8, where the alluvium is very deep, a thick alluvial aquifer overlies the Peacock formation. This water bearing stratum is in turn overlain by a blanket of much less pervious alluvial deposits. In this case, it is likely that relief wells will be needed to reduce the danger of uplift pressure rupturing the less pervious overburden.

At Site No. 12, there are scattered deposits of alluvium with high gypsum concentrations. The gypsum occurs as sand size grains in SM and ML soils. These soils should be removed where encountered in the foundation and avoided for use in the embankment.

Some seepage in abutments along joint and bedding planes in conglomerates and through slightly indurated sand beds could necessitate minor drainage measures at several sites.

Berms on downstream embankment slopes, as well as upstream, may be required for erosion control purposes at Site Nos. 3, 5, and 7 because of high embankments. At Site No. 1, where the use of a considerable volume of SM in the embankment is expected, a downstream berm may be necessary for stability purposes.

Rock excavation is expected in the removal of sandstone and conglomerate from the emergency spillway areas of 7 structure sites. These sites and the estimated percent of rock in emergency spillway excavation are:

Site Number	Percent Rock
5	less than 10
1 and 2	10
3 and 6	20
4	25
7	30

Some rock excavation will also be involved at Site No. 5 in cutting the steep right abutment to a flatter slope before embankment materials are put into place.

At some sites, sand beds, which are highly susceptible to erosion will be exposed in emergency spillway excavation. These cuts will be vegetated as soon as possible after construction.

Further Investigations

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

Ground Water Investigations

Borings were made with core drilling equipment to study the ground water aspects of the watershed and to estimate the effects of the project on ground water. The borings were made at selected locations along the stream channels and flood plains of Duck, Dockum, and Cottonwood Creeks.

Permian shale underlies extensive valley alluvial deposits. This alluvium contains an aquifer, ranging in thickness up to 25 feet, with its base at the upper surface of the shale. This aquifer has a hydraulic gradient, ranging from 15 to 20 feet per mile, toward the southeast or in the general direction of stream flow. It is recharged by downward percolation of rainfall through the alluvium and by seepage of runoff water from stream channels.

Geologic conditions at floodwater retarding structure sites are not favorable for any significant increase in recharge by seepage from sediment pools.

Upstream from VS-23 (figure 1), beds and lenses of clay occur within sandy alluvium between the ground surface and the water table, thereby drastically limiting the rate of vertical permeability. Downstream from VS-23, restricting clays are not a factor, but the water table is either at or very near the stream channel bottom. Thus, there is little opportunity for increasing ground water recharge while the water table is at its normal position.

Natural recharge is sufficient to maintain the water table near the stream channel bottom, except during summer months when pumpage is heavy and during extremely dry periods.

Increased recharge will occur as a result of prolonged release flows from floodwater retarding structures only when the water table is below normal. Since this will not be a frequent occurrence, no benefits were claimed for increased groundwater recharge.

Economic Investigations

Selection of Evaluation Reaches

In order to evaluate the effects that various combinations of structural measures would have on the reduction of damages and because of the difference of damageable values, frequency of flooding, and flood plain characteristics, the flood plain was divided into 10 evaluation reaches (figure 1).

Determination of Damages

Damage schedules were obtained within each reach of the flood plain from landowners and operators and covered approximately 70 percent of the flood plain. Information collected was used to determine land use and crop distribution, yield data, expected changes in land use, characteristics of flooding, damage to crops, pastures, other agricultural damage, and historical information on flooding. Information from these schedules plus information from local agricultural workers familiar with the area was used as a basis for making the estimates used in the economic evaluations.

Flood plain land use was mapped in the field. A separate damageable value was determined for each evaluation reach. Average flood free yields were based on information obtained from landowners and supplemented by information from local agricultural leaders with allowances made for expected yield increases from improved technology during the life of the project. Annual crop, pasture, other agricultural and non-agricultural damages were determined by using a synthetic flood series for a 1-, 2-, 4-, 10-, 20-, 50-, and 100-year frequency storm. Damages were related to area inundated and depth of inundation. Crop and pasture damages were also related to growing seasons. Allowances were made for the occurrence of more than one flood during a growing season by discounting the crop and pasture damages. Damages in some reaches were discounted to reflect land loss expected to occur from streambank erosion in absence of a project.

Damage to agricultural property such as fences, farm roads, equipment, irrigation wells, and irrigation water distribution systems was estimated from information collected in the field. Road and bridge damages were based on information obtained from county and state road officials. These damage estimates were related to size and frequency of floods as reflected by high water elevations and peak discharge.

The monetary value of the physical damage to flood plain land from deposition of sediment and from erosion was based on the value of production lost. Allowances were made for the time lag necessary for recovery and for the nonrecoverable loss in production. Also taken into account was the increase in rate of sediment damages expected to occur without the protection of structural measures. The monetary value of the permanent loss of land was estimated using the procedure outlined in Chapter 5 of the Soil Conservation Service Economics Guide. Flood plain scour damage was related to depth of flooding with weight given to increased velocity from the deeper flows. Reduction in monetary damages for sediment deposition is based on the effectiveness of land treatment and critical area treatment measures, trap efficiency of planned floodwater retarding structures, and the average annual area flooded.

Indirect damages involve such items as interruption of travel and detours due to flooding, re-routing, and delays of school buses and mail deliveries, and losses in business sustained by business establishments in the area. It was determined that 10 percent of the direct damages would be an equitable and conservative estimate for indirect damages.

Benefits from Reduction of Damages

Floodwater, scour, erosion, sediment, and indirect damages were calculated under the following conditions: without project, with land treatment; with land treatment and floodwater retarding structures; and with land treatment, floodwater retarding structures, and streambank protection. The difference between the average annual damages for each progressive increment of protection constitutes the benefits assigned to that increment.

Damage reduction benefits were allocated to each floodwater retarding structure on the basis of drainage area. Benefits were allocated to streambank protection structures according to the amount of land loss that each structure is expected to prevent.

Incidental Benefits from Water Management

Water management benefits will occur incidental to the installation of the floodwater retarding structures proposed in this plan. Flood prevention was the only purpose considered in the location of these structures and no additional Public Law 566 costs are involved in obtaining incidental benefits from the storage in the sediment pools of the structures. When the structures are installed, it is estimated that the sediment pools will have an initial total capacity of 4,139 acre-feet. With the expected sediment deposition in the sediment pools, the capacity will eventually decline to zero.

Investigations were made to determine the beneficial uses that would be made of additional water made available from this source.

Incidental recreation benefits will accrue to the sediment pools. Present recreation facilities, particularly for fishing and hunting of water fowl, do not meet the desires of the people in the area. These pools of water will provide additional facilities for these activities. All of these pools are expected to be open to the public, but some will be open on a fee-charge basis or by free admission with the landowners permission.

Recreation benefits were estimated in monetary terms for each of the proposed floodwater retarding structures. Factors considered in making the estimates were population within a radius of 40 miles, size of the sediment pools, and accessibility of the site. The expected recreational use of the 12 sites was estimated to be 3,750 visitor-days annually. These benefits, after allowing for associated costs and discounting to allow for a 5-year lag in accrual with a decline to zero use 50 years hence, will total an estimated $1,096 annually.

Investigations revealed that incidental water management benefits from irrigation will accrue to some sites in the proposed plan. These benefits will result from the planned use of water from 2,883 acre-feet of initial storage capacity in the sediment pools of structures Nos. 1 and 5.

Water yield studies indicate an adequate water supply will be available for irrigation of the acreages from which benefits are claimed. Necessary

water rights are to be obtained by the landowners.

These benefits will be derived from increased net income from the land to be irrigated. In calculating the increase in net income, allowances were made for associated costs, time lag in accrual of benefits for 40 years with a decline to zero use 50 years hence because of the decreasing capacity of the sediment pools. The benefits are estimated to total $1,508 annually.

Irrigation

Floodwater retarding structure No. 5 was designed to include 198 acre-feet of storage for irrigation water supply. The cost of this additional storage is considered a non-project cost and is not included in Tables 1 or 2. Costs were allocated in accordance with the "Use of Facilities" method as follows:

Purpose	Acre-Feet	Percent
Flood Prevention	5,908 1/	96.76
Irrigation Water Storage	198	3.24
Total	6,106	100.00

1/ Includes 2,797 acre-feet of sediment storage.

Appraisal of Land and Easement Values

Areas that will be used for project construction and areas to be inundated by pools of reservoirs were determined. Net income from production to be lost in these areas after installation of the project was compared with the appraised value of the land amortized over the period of project life. It was considered, there would be no production in the sediment pools and that all land covered by the detention pools would be grassland. The costs of land, easements, and rights-of-way for the structures were determined by appraisal in cooperation with representatives of the sponsoring local organizations. The structure site costs were based on appraisals of the value of the easements.

The average annual net loss in production and associated secondary losses, based on long-term prices, with the sites were calculated and compared with the amortized cost of the structure sites. The annual value of the easements exceeded the annual loss in production and associated secondary losses; therefore, the easement value was used in economic justification.

Secondary Benefits

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

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

were considered to be 10 percent of the direct damage reduction benefits accruing to structural measures. Benefits induced by the project were considered to be at least 10 percent of the incidental benefits.

Secondary losses resulting from installation of structural works of improvement were calculated and used in determining "negative project benefits".

Details of Methodology

The evaluation of flood damages were made by flood routing a synthetic storm series. The frequency method was used in the calculations. Details of the procedures used under this method of evaluations are described in the Soil Conservation Service Economics Guide for Watershed Protection and Flood Prevention dated March 1964.

Fish and Wildlife Investigations

The Bureau of Sport Fisheries and Wildlife of the Fish and Wildlife Service, United States Department of the Interior, in cooperation with the Texas Parks and Wildlife Department made a reconnaissance study of the proposed Duck Creek watershed project. The following is quoted from their report dated June 25, 1964:

> "Duck Creek is an intermittent stream with virtually no fisheries. The stream flows during periods of heavy rainfall. Channel catfish, flathead catfish, largemouth bass, and other sunfish are present in Duck Creek.
>
> "Hunting in the watershed is principally for fox squirrels and bobwhites. Consent of the landowners is necessary for hunting squirrels and quail. No land is leased.
>
> "Our reconnaissance of the proposed Duck Creek Watershed indicates that fish and wildlife generally will be benefited by the project. Permanent impoundments formed by floodwater retarding structures will increase opportunities for fishing and provide some habitat for migrating waterfowl. Reduced runoff of floodwaters will be beneficial to ground-nesting species of wildlife in the downstream floodplain. Inclusion of additional land-improvement measures and the construction of farm ponds also will offer opportunities for the enhancement of fish and wildlife resources in the watershed.
>
> "Most of the watershed is cultivated or in range, and contains small acreages of timber. Clearing of brush and timber for the construction of floodwater retarding structures, farm ponds, terraces, diversions, and other structural practices will eliminate wildlife habitat, primarily for fox squirrels. Clearing of bottomland timber and brush undoubtedly will be accelerated with flood control, further reducing wildlife habitat.
>
> "Duck Creek Watershed provides excellent opportunities for the development of fish and wildlife under the provisions of the Watershed Protection and Flood Prevention Act. Watershed planning and practices should

include proper water and land management to achieve optimum fishing and hunting. With a minimum of planning and expense, floodwater retarding structures, farm ponds, erosion prevention, and soil-building measures may be made to produce fish and wildlife in addition to their other conservation functions.

"The impoundment of water will not result automatically in additional good fishing in the watershed. Owners of new water areas or those persons responsible for managing new water resources should seek professional advice from the Texas Parks and Wildlife Department in the preparation of fishery management plans to insure the establishment and maintenance of good fishing. The same principle applies with respect to the development and improvement of wildlife habitat.

"Wildlife losses would be minimized if care were taken to retain or replace woody vegetation wherever possible when applying land-treatment measures. Wildlife habitat could be improved in the watershed by planting idle lands to those species of trees, shrubs, and grasses which would be valuable as food and cover for wildlife.

"Maximum fishing and hunting would be realized if public access were provided to the floodwater retarding structures.

"It is recommended:

1. That clearing specifications for the construction of floodwater retarding structures, diversions, terraces, farm ponds, and other structural measures allow for the retention or replacement of all possible woody vegetation.

2. That plant species having value as food and cover for wildlife be planted near floodwater retarding structures and be included in erosion-control plantings.

3. That public access be provided to the floodwater detention sites.

4. That the owners of reservoirs and ponds or those persons responsible for the management thereof, seek professional advise from the Texas Parks and Wildlife Department in all matters concerning the establishment and maintenance of fish and wildlife species and their habitat.

"No detailed studies by the Bureau of Sport Fisheries and Wildlife are considered necessary at this time."

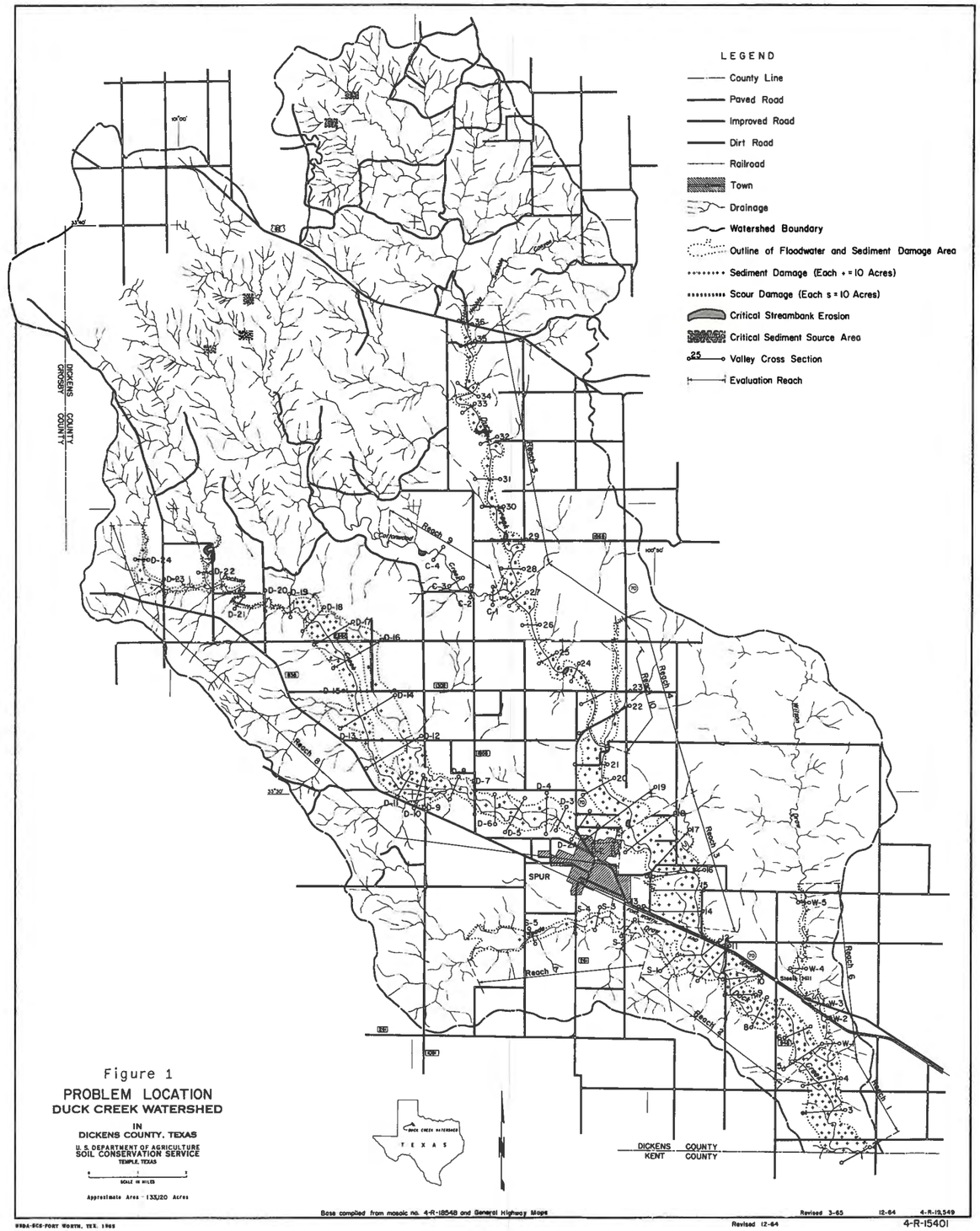


Figure 1
PROBLEM LOCATION
DUCK CREEK WATERSHED
IN
DICKENS COUNTY, TEXAS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

USDA-SCS-FORT WORTH, TEX. 1965

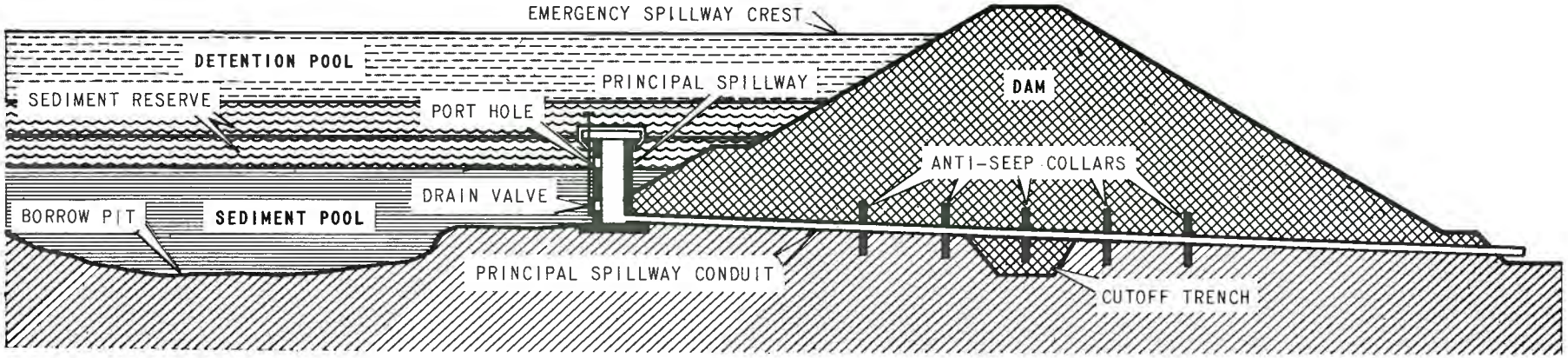


Figure 2

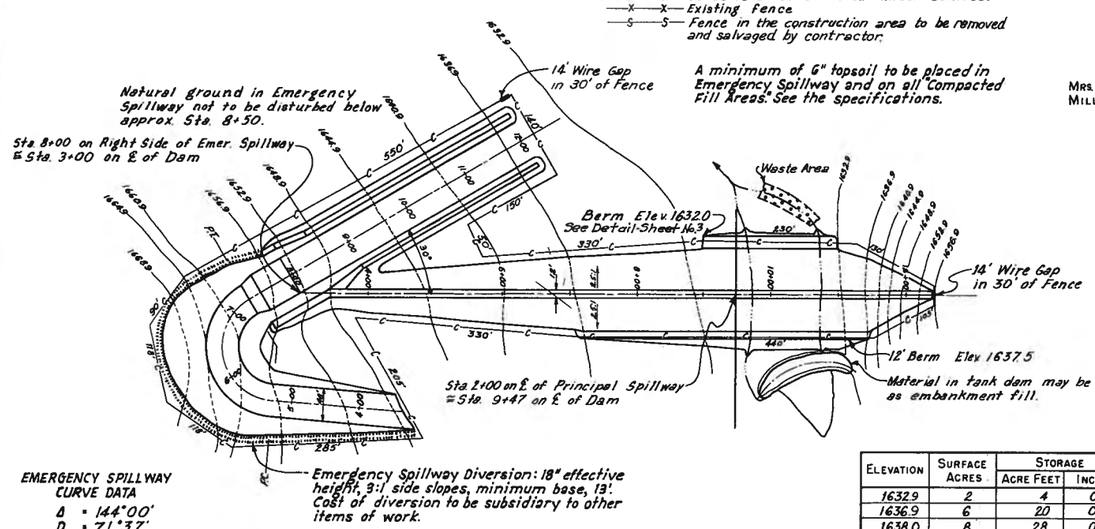
SECTION OF A TYPICAL FLOODWATER RETARDING STRUCTURE

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
USDA-SCS-FORT WORTH, TEX. 1965

Rev. 3-65 4-L-10,071

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

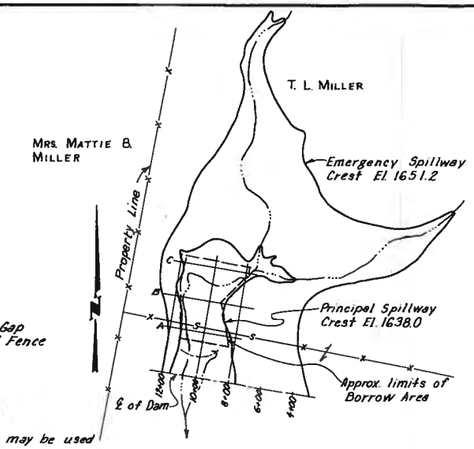
A minimum of 6" topsoil to be placed in Emergency Spillway and on all Compacted Fill Areas. See the specifications.



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

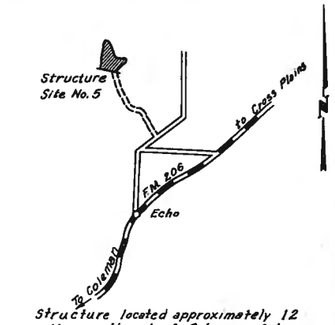
PLAN OF EMBANKMENT AND SPILLWAYS

0 100 200 300 400 500
SCALE IN FEET



GENERAL PLAN OF RESERVOIR

0 400 800 1200 1600
SCALE IN FEET



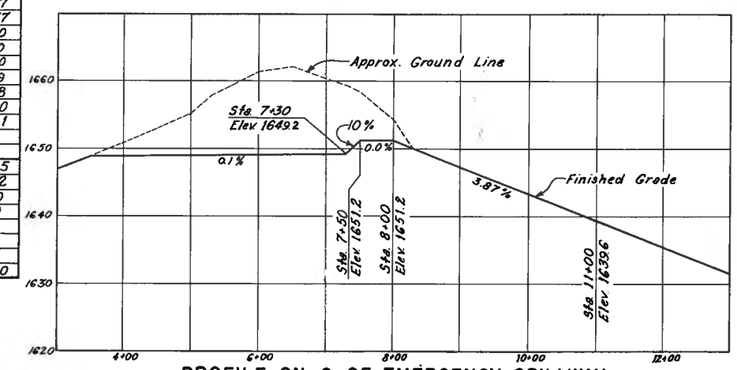
Structure located approximately 12 miles northeast of Coleman, Coleman County, Texas.

VICINITY MAP

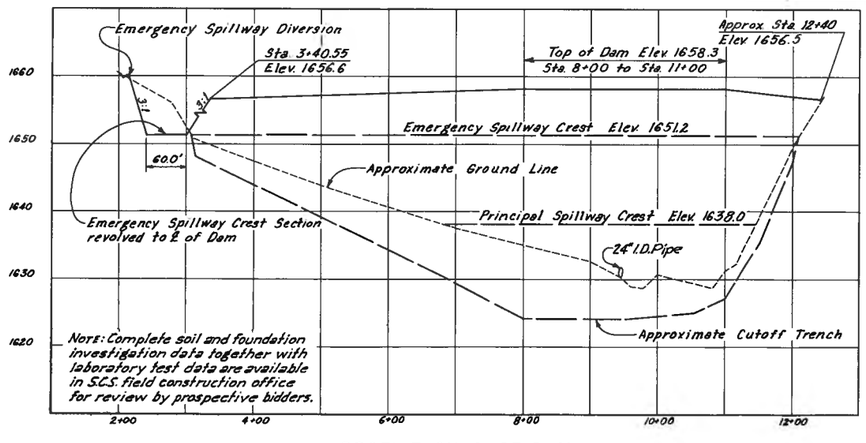
0 1 2 3 4
SCALE IN MILES

ELEVATION	SURFACE ACRES	STORAGE	
		ACRE FEET	INCHES
1632.9	2	4	0.05
1636.9	6	20	0.27
1638.0	8	28	0.37
1640.9	14	60	0.80
1644.9	20	128	1.70
1648.9	29	226	3.00
1651.2	36.4	301	3.99
1652.9	42	368	4.88
1656.9	53	558	7.40
1660.9	64	792	10.51

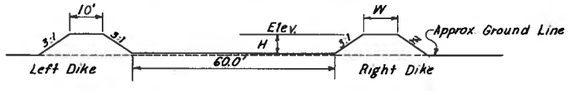
Top of Dam (Effective) Elev.	1656.5
Emergency Spillway Crest Elev.	1651.2
Principal Spillway Crest Elev.	1638.0
Sediment Pool Elev.	1638.0
Drainage Area, Acres	904
Sediment Storage, Acre Feet	32
Floodwater Storage, Acre Feet	269
Max. Emergency Spillway Cap., c.f.s.	1830



PROFILE ON ℄ OF EMERGENCY SPILLWAY



PROFILE ON ℄ OF DAM



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

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

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

TYPICAL SECTION — EMERGENCY SPILLWAY

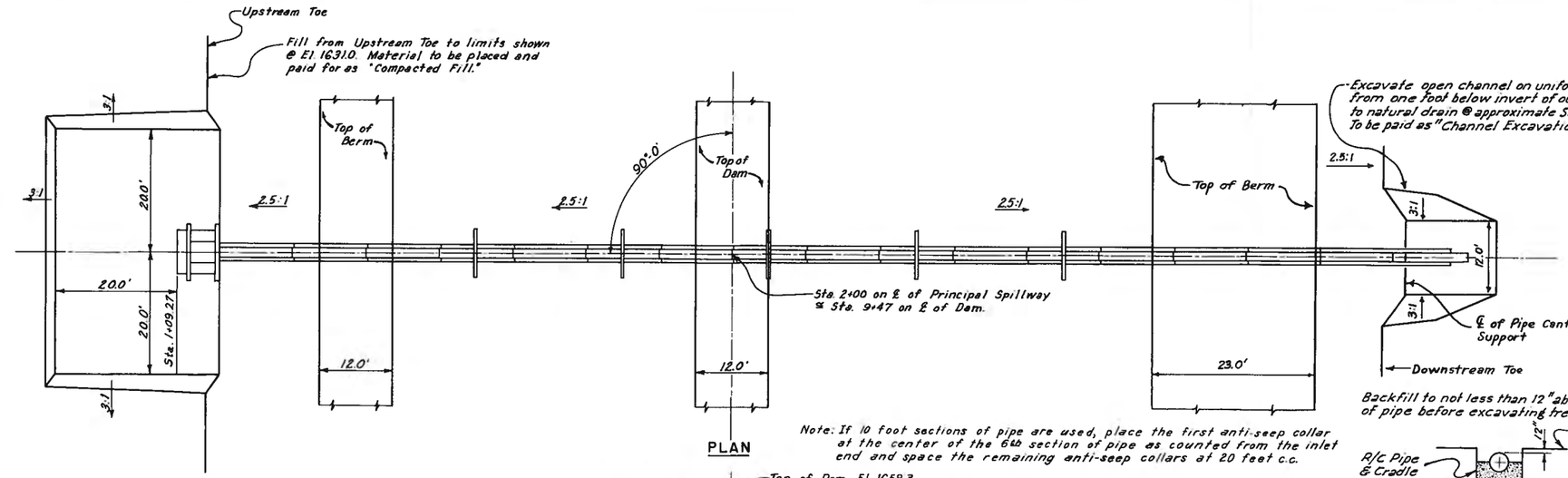
Figure 3

TYPICAL
FLOODWATER RETARDING STRUCTURE
GENERAL PLAN AND PROFILE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed W.E.C.	Date 3-61	Approved by: HEAD, ENGINEERING & WATERSHED PLANNING UNIT, FORT WORTH, TEXAS	
Drawn W.E.C. & H.R.T.	3-61	STATE CONSERVATION ENGINEER, S. C. S.	
Traced H.R.T.	3-61	TEMPLE, TEXAS	
Checked W.E.C. & G.W.T.	4-61	Sheet No. 2 of 8	Drawing No. 4-E-15,357

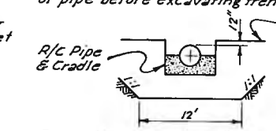
USDA-SCS-FORT WORTH, TEX. 1965



PLAN

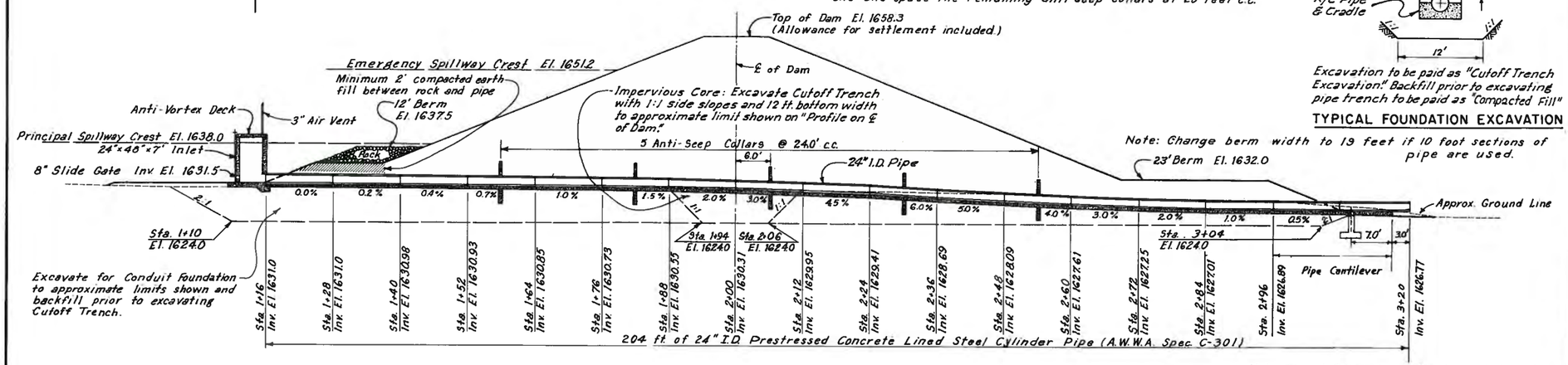
Note: If 10 foot sections of pipe are used, place the first anti-seep collar at the center of the 6th section of pipe as counted from the inlet end and space the remaining anti-seep collars at 20 feet c.c.

Backfill to not less than 12" above top of pipe before excavating trench.



Excavation to be paid as "Cutoff Trench Excavation." Backfill prior to excavating pipe trench to be paid as "Compacted Fill"

TYPICAL FOUNDATION EXCAVATION

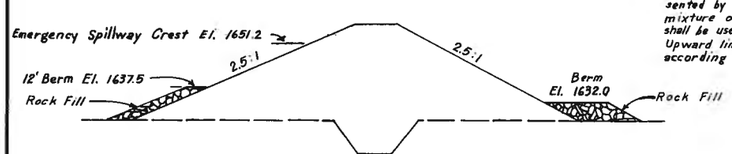


SECTION

PRINCIPAL SPILLWAY

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

Figure 3A



TYPICAL SECTION

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

MATERIALS					
LAB. TEST		COMPACTION REQUIREMENTS			Lab. Curve
Modified		Min. Dry Density	Moisture Range		
Max. Dry Den.	Opt'm Moist	Lbs. Per Cu. Ft.	Percent From	To	No.
119.5	12.5	107.2	13.0	UP	1
146.0	6.1	136.7	6.1	UP	2
126.1	10.9	119.9	10.9	UP	3
136.5	11.5	112.0	12.0	UP	4

If the material being placed in the fill contains 1/4 inch or larger material in amounts differing from the percentages found in the laboratory sample, the minimum dry density and moisture requirement will be corrected for this variation.

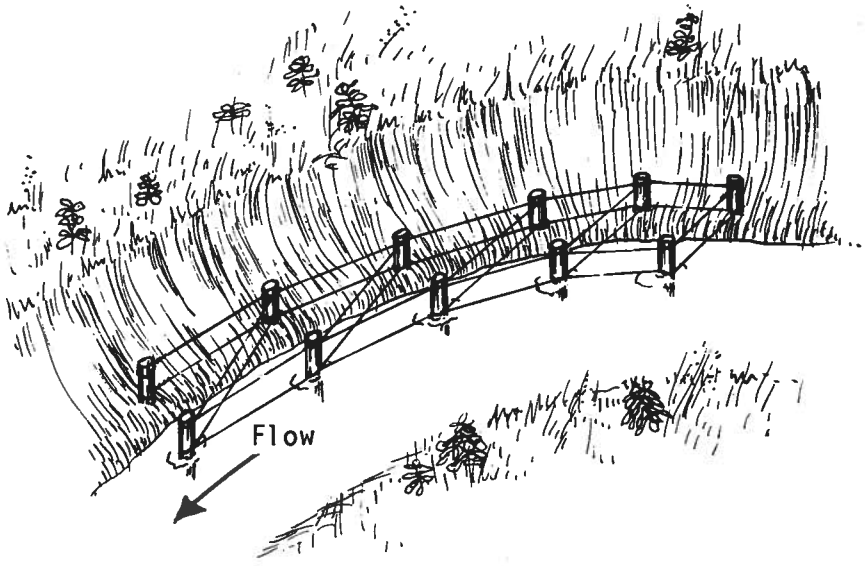
EMBANKMENT DATA

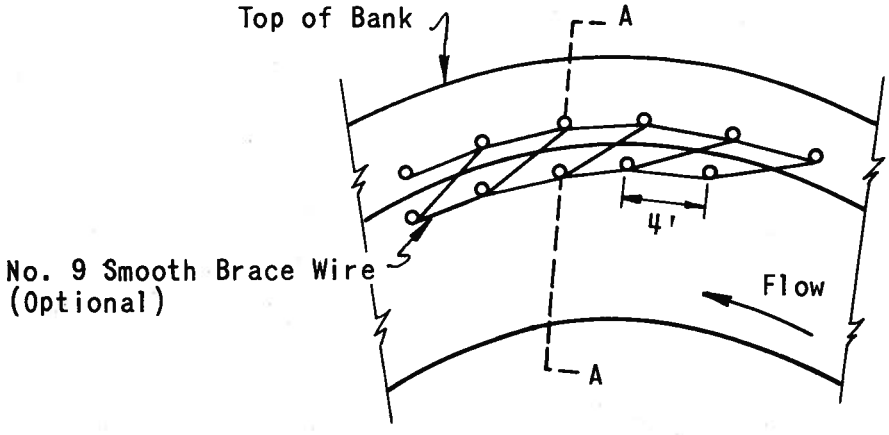
TYPICAL
FLOODWATER RETARDING STRUCTURE
STRUCTURE PLAN AND SECTION

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

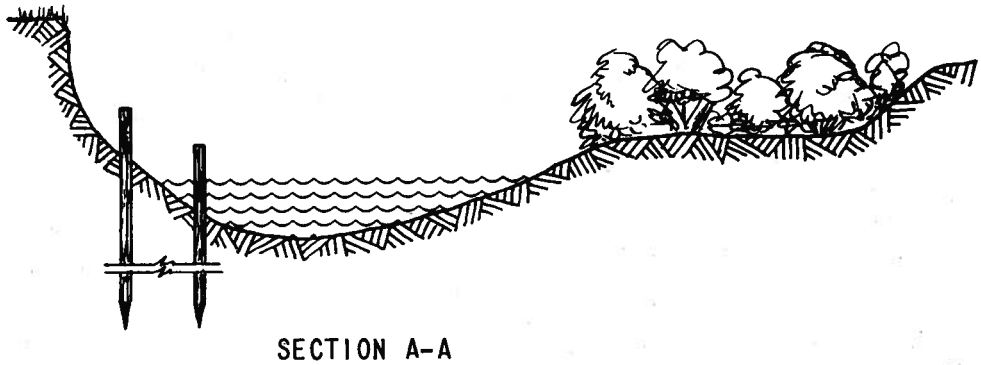
Designed W.E.C.	3-61	Approved by	HEAD, ENGINEERING & WATERSHED PLANNING UNIT, FORT WORTH, TEXAS
Drawn W.E.C. & H.R.T.	3-61		STATE CONSERVATION ENGINEER, S. C. S.
Traced H.R.T.	3-61	TEMPLE, TEXAS	
Checked W.E.C. & G.W.T.	4-61	Sheet No. 3 of 8	Drawing No. 4-E-15,357

USDA-SCS-FORT WORTH, TEX. 1965





PLAN



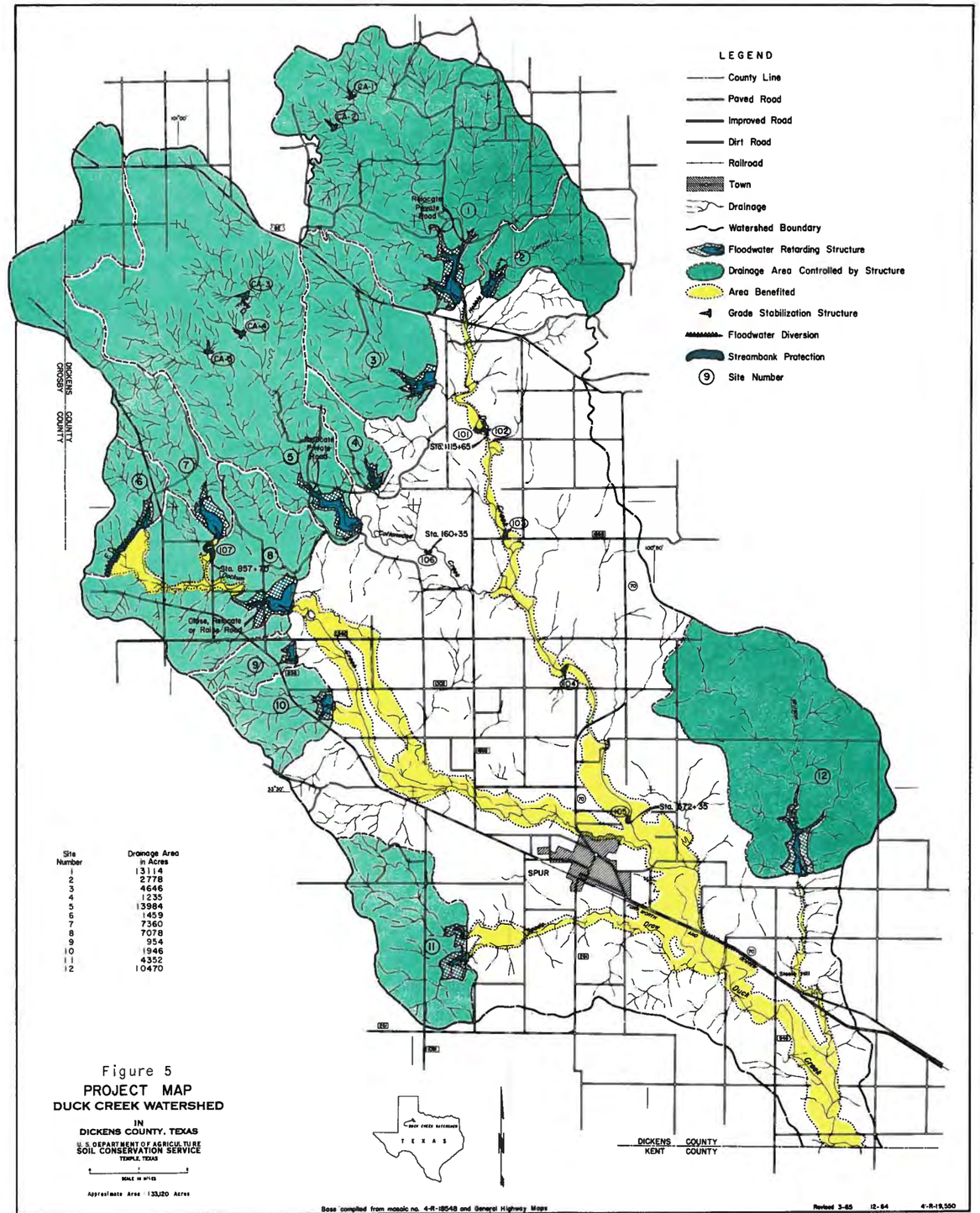
SECTION A-A

Figure 4

STRUCTURE FOR STREAMBANK PROTECTION

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, Temple, Texas 12-64 4-L-19604

USDA-SCS-FORT WORTH, TEX. 1965



Site Number	Drainage Area in Acres
1	13114
2	2778
3	4646
4	1235
5	13984
6	1459
7	7360
8	7078
9	954
10	1946
11	4352
12	10470

Figure 5
PROJECT MAP
DUCK CREEK WATERSHED
IN
DICKENS COUNTY, TEXAS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

SCALE IN MILES

Approximate Area 133,120 Acres

Base compiled from mosaic no. 4-R-18548 and General Highway Maps

Revised 3-65 12-64 4-R-19,550

Revised 12-64

4-R-15401

USDA-SCS-FORT WORTH, TEX. 1965