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INVENTORY AND USE OF SEDIMENTATION DATA IN TEXAS

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INVENTORY AND USE OF SEDIMENTATION DATA IN TEXAS

INTRODUCTION

This report brings together all available, pertinent data on sedimentation records in order to furnish the best possible estimates of average annual sediment production rates for watersheds larger than 100 square miles throughout the State. These rates have been established by using a wide variety of data, including suspended sediment measurements and reservoir sedimentation surveys made by various State and Federal agencies.

Procedures used in compiling, analyzing, and summarizing these data are discussed, and a map showing annual rates of sediment production in acre-feet per square mile for all major sub-basins in the State is included. Curves indicating average annual rates of sediment production by land resource areas for watersheds ranging from 100 to 10,000 square miles in size are shown.

The general sedimentation characteristics of the 14 major land resource areas of the State and the influence these characteristics have on the planning, design, and construction of works of improvement affecting the conservation and use of water are discussed. Estimated reductions in rates of annual sediment production due to land treatment measures are listed for these land resource areas. Sediment problems in the 17 major river basins of the State are discussed as are the various types of sediment damages, including sedimentation of reservoirs. A bibliography is attached showing the more important published information on sedimentation in Texas.

AGENCIES COLLECTING SEDIMENTATION DATA

Various State and Federal agencies have been engaged in making sediment load measurements in Texas for approximately 70 years. The first known suspended sediment station in the State was established by the International Boundary and Water Commission of the United States and Mexico on the Rio Grande at El Paso in 1889 (see ref. 1). From 1900 to 1914 several additional stations were established on the Rio Grande by the IBWC. From 1914 to 1923 all sediment load measurements were discontinued. In 1923 the IBWC program was reactivated and there are now several stations on the Rio Grande between El Paso and Brownsville.

Since 1924 the Texas Board of Water Engineers has established a total of 52 sediment load measuring stations; 25 of which are presently active (see ref. 2). These 25 stations are distributed over 12 of the major river basins of the State.

The Corps of Engineers is presently carrying on suspended sediment measurements with three stations located in two of the major river basins of the State.

The U. S. Geological Survey, in cooperation with the Texas Board of Water Engineers, the Bureau of Reclamation, the Corps of Engineers, and the Soil Conservation Service, has a limited number of investigations underway including suspended load and bed load measuring stations.

TYPES OF SEDIMENT LOAD DATA

Most of the sediment load data accumulated in Texas to date have been in the form of suspended load measurements or that which is in suspension in streamflow. Particles making up at least a portion of the sediment load of many streams which bounce or roll along the bottom or bed of the stream and are carried or moved downstream by streamflow are known as the "bed load". Sediment accumulation in reservoirs may be determined by making actual reservoir surveys. Suspended load measurements have been made by various Federal and State agencies in the major basins of the State, largely from 1924 to the present (see ref. 3 and 4). In addition to suspended sediment load measurements, numerous reservoir sedimentation surveys have been made in the State. The Soil Conservation Service has made most of these measurements since 1935. Prior to 1930 T. U. Taylor (see ref. 5) made a considerable study of the sedimentation of reservoirs. In the 1920's the Texas Board of Water Engineers and the Bureau of Agricultural Engineering (now the Division of Irrigation, Soil Conservation Service) made cooperative studies of reservoir silting which were described in a 1933 bulletin by O. A. Faris (see ref. 6). For further information the reader is referred to Sedimentation Bulletin 6 (see ref. 7).

EVALUATION OF DATA

Several factors must be considered in evaluating and analyzing sediment load data and reservoir sedimentation survey data for various uses and purposes. One of the most important of these factors is the length of the individual records. Short-term records are of doubtful reliability, particularly where rainfall, runoff and stream flow may be considerably above or below normal for the period of record. Therefore, annual rates of sediment production which are based on continuous, long-term records are much more reliable.

In addition to the length of the record, the number of observations is most important. Periodic or irregular sampling does not reflect average sediment load characteristics of a stream nor does sampling only the surface portion of non-turbulent flow. It is important, therefore, that integrated samples be taken daily throughout the stream cross section at regular intervals. Additional samples should be taken during fluctuating stages of the stream in order to obtain the sediment load characteristics during rising and falling stages. Only these more reliable type of suspended load measurement records were used in developing the annual sediment production rate curves which are included in this report.

Rates of sediment production based on reservoir sedimentation surveys also are considered more reliable when a reservoir is of sufficient age to reflect a wide range of rainfall and runoff conditions covering a long period of time. Sediment volumes in a reservoir may be determined by comparison of original contour maps with maps showing the present topography of the sediment surface or by direct measurement of sediment thickness. Two methods of survey are used by the Soil Conservation Service - the contour method and the range method.

Details concerning equipment, survey procedures and method of computation are contained in USDA Technical Bulletin 524, "Silting of Reservoirs" (see ref. 8).

Methods and equipment used in sampling suspended sediment are often of prime importance in establishing the reliability of this type of sediment record. One of the most widely used samplers in Texas is the U. S. Department of Agriculture or Texas bottle sampler (see ref. 2). This sampler was designed and tested by an engineer assigned to Irrigation Investigations, U. S. Department of Agriculture, and the Texas Board of Water Engineers. It consists of an eight-ounce bottle attached to a six-pound lead torpedo. The sampler has been used continuously since 1924 by the Texas Board of Water Engineers in its suspended load measuring program, and during the past 34 years daily samplings totalling over 150,000 have been made with it at 52 stations (some now discontinued) in the State.

In use, this equipment is lowered over the side of a bridge by means of a length of cotton rope. Samples are taken within the surface-foot of the stream in order to trap only the suspended material. Samples are then properly labeled and sent to the laboratory for analysis. U. S. Geological Survey stream gaging records at the same point are used to compute the suspended load.

Many other types and models of suspended sediment samplers have been used throughout the United States. A partial list of the more widely used samplers follows: (See ref. 3.)

U. S. Geological Survey Colorado sampler.
U. S. Geological Survey horizontal bottom depth-integrating sampler.
U. S. Geological Survey vertical bottom depth-integrating sampler.
U. S. D-43 depth integrating sampler.
Mississippi River Commission sampler.
New Orleans District, Corps of Engineers, vertical trap sampler.
Omaha District, Corps of Engineers, time-integrating sampler.
Ohio River Division, Corps of Engineers, silt sampler.
U. S. P-43 point integrating sampler.
U. S. P-44 point-integrating sampler.
Rock Island District, Corps of Engineers, time-integrating sampler.
St. Paul District, Corps of Engineers, bottle sampler.
Tennessee Valley Authority horizontal sampler.
U. S. Bureau of Public Roads Topock sampler.
U. S. Bureau of Reclamation Yuma sampler.
Vicksburg District, Corps of Engineers, horizontal-type trap.
Vicksburg District, Corps of Engineers, vertical-type trap.

Detailed descriptions of these and other samplers may be found in a report of the cooperative studies of methods used in measurement and analysis of sediment loads in streams, planned and conducted jointly by the Tennessee Valley Authority, Corps of Engineers, Department of Agriculture, Geological Survey, Bureau of Reclamation, Indian Service, and Iowa Institute of Hydraulic Research (see ref. 9). Characteristics of several types of samplers also are given in a report which was published in March 1948 as Report No. 8 in the above series of reports (see ref. 10). Federal agencies represented on the Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, have developed standard point and depth integrating samplers and a bed material sampler which are now used exclusively by these agencies.

NEED FOR ADDITIONAL SEDIMENT LOAD DATA

Expansion of Federal and State programs of flood control, water-power development, reclamation, soil conservation, navigation and water supply during the past two decades has intensified the need for accurate sediment data.

The selection of sediment-load measuring stations is based on the need for basic data in connection with such problems as the determination of sediment production rates from land resource areas, evaluation of sedimentation damages, development of design data for reservoir sedimentation, channel aggradation and degradation, channel rectification and control, and maintenance of navigation channels.

The following criteria should be used in selecting sediment-load stations: (See ref. 11.)

1. All stations should be located at or near streamflow gaging stations.
2. All stations should be operated long enough to reflect sediment discharge characteristics over a range of runoff conditions representative of the long-term expectancy. Normally this should not be less than 10 years.
3. Integrated measurements at the stream cross section should be made to reflect total rather than suspended load.

Reservoir sedimentation surveys can be used to determine annual and/or long-term rates of sediment production from contributing areas. The following criteria should be used in selecting representative reservoirs for surveys.

1. Data from sedimentation surveys should reflect a close approximation of the sediment inflow to the reservoir. This condition is met if both the deposits in the reservoir and the sediment outflow through the dam are measured or if the detention-storage time is such to desilt practically all of the sediment-laden inflow. Experience indicates that at least 90 percent of the sediment inflow is retained in reservoirs having a storage capacity of 0.2 acre-foot per acre-foot of annual inflow.
2. The sediment-contributing area should not contain upstream reservoirs which have more than a minor effect on the sediment inflow to the surveyed reservoir, unless complete information about sediment inflow, outflow and retention is available for the upper reservoirs.
3. Reservoirs which are planned for periodic resurveys should be properly monumented.

There is a particular need for additional sediment load data on small tributary streams in Texas. This type of information is scarce on watersheds ranging in size from 100 to 1,000 square miles. Such information would be of particular value in specific problem areas for establishing sediment storage requirements for proposed larger reservoirs ranging in capacity from 10,000 to 100,000 acre-feet.

It is recognized that all but an insignificant percentage of the annual sediment load from these small tributary streams is carried by the large flows occurring in a few days during the year (see ref. 12). Long observations have given conclusive evidence that the sediment and water hydrographs do not coincide. Therefore, the most important requirement for the computation of sediment load in small tributary streams is that sufficient samples be taken at the proper times, particularly during rising stages to adequately define the sediment hydrographs. It also is important that the total load, consisting of both suspended and the bed material load be sampled.

The need for additional sediment load data and reservoir sedimentation survey data is most acute in the following land resource areas of the State: Trans-Pecos, Edwards Plateau, Rio Grande Plain, and the East Texas Timberlands. Estimates of sediment production rates which are used at present in the design and construction of reservoirs or other works of improvement must be based on very meager existing data in these areas.

A particular need also exists for such additional information on the bed material load of representative streams in the western or semi-arid and arid sections of the State. In such areas as the Trans-Pecos, for example, it is believed that the greater part of the total sediment transported by streams is bed load rather than suspended load.

In connection with the above needed studies, other related sediment problems of a special nature are becoming more important and should receive further study. These include (1) sedimentation and change in channel gradients above reservoirs, (2) degradation of channels below reservoirs, (3) ultimate volume and distribution of sediment in reservoirs and (4) trap efficiency of reservoirs. Some investigations which have been initiated in Texas in recent years are:

1. Resurvey of degradation ranges on the Red River below Denison Dam (Lake Texoma) - Corps of Engineers.
2. Special study to determine distribution of sediment in the San Angelo reservoir - Corps of Engineers.
3. Resurveys of selected floodwater retarding structures in the Trinity, Brazos and San Antonio watersheds to determine sediment accumulation, distribution and density - Soil Conservation Service.
4. Measurement of both inflow and outflow on two floodwater retarding structures in the Trinity River watershed to determine trap efficiency-U. S. Geological Survey in cooperation with the Texas Board of Water Engineers. A similar study is being conducted on one floodwater retarding structure in the San Antonio River watershed - U.S.G.S. cooperating with the Soil Conservation Service.

PROCEDURES AND METHODS USED IN DEVELOPING RATES OF SEDIMENT PRODUCTION

No single criterion is sufficient to establish a particular sediment production rate over a wide area. However, criteria, consisting of size of drainage area, land use (cover), soils, geology, topography, and climatic characteristics of watersheds, when used in combination, make it possible to develop indices of average sediment production rates for specific land resource areas with a reasonable degree of accuracy.

The rates developed in this study represent an average of the rates developed from a limited number of reservoir sedimentation surveys and/or sediment load measurements in each land resource area. As such, they give an indication of what may be expected, in terms of sediment production rates, from the average watershed in a given area.

In this study considerable reliance was placed on size of drainage area as a basis for estimating sediment production rates but only after other factors, known to influence these rates, had been taken into consideration. Sediment production rates per unit of drainage area have been shown to be associated with size of drainage area. A plotting of sediment production rates, in acre-feet, against square miles of sediment-contributing area usually indicates a distinct trend toward lower rates of production per unit of area with increasing size of drainage area. However, there may be considerable spread in the plotted points, particularly for small watersheds, because of the lack of uniformity among the other characteristics of watersheds that have an influence on sediment production rates. Therefore, if a reasonable uniformity of these characteristics can be established for a given area, the size of drainage area becomes an effective measure for estimating the sediment production rates.

Relatively uniform areas, from the standpoint of the characteristics of watersheds that influence sediment production rates, are shown on the production rate map, Plate I. These fourteen sub-divisions were taken from a land resource area map of the State compiled by the Soil Conservation Service, Texas Agricultural Experiment Station, and the Texas Agricultural Extension Service (see ref. 13). In some cases these land resource areas were sub-divided into smaller sections in an effort to decrease the variations brought about by such factors as land use (cover), soils, topography and other variables that influence sediment production rates.

Most of the sediment production rate data and other pertinent information used in developing the sediment production rate curves for the various land resource areas are shown in tables 1 and 2. However, the production rate data for the Texas portion of the Trans-Pecos area was supplemented by data from the New Mexico portion of this land resource area. Likewise, the production rate data for the North Central Prairies and Rolling Plains land resource areas in Texas were supplemented by data from the Oklahoma portion of these areas. These data from New Mexico and Oklahoma are not shown in table 1 or 2.

Measured sediment production rate data from sediment load stations were converted to adjusted sediment production rate, column 9 table 1, by making adjustments for volume weight and estimating the unmeasured bed load. The reservoir sediment production rates, column 7 table 2, have been adjusted for reservoir trap efficiency.

Trap efficiency of reservoirs was computed by the capacity-inflow ratio method developed by Brune (see ref. 14). Adjustment factors for unmeasured bed load at various suspended sediment stations were based on stream gradients, composition of bed material, sources of sediment, watershed soils, geology, and volume and character of stream discharge, particularly maximum annual flood discharge. In making the adjustments for bed load it was estimated that the suspended sediment load represented from 70 to 100 percent of the total sediment load at the various points of measurement, depending on the factors listed.

The acre-foot sediment production rate data from most suspended sediment stations is based on an estimated dry weight of cubic foot of sediment that is subject to alternate wetting and drying. Alternate wetting and drying results in compaction and the sediment occupies less space than a like amount of sediment continuously submerged in a reservoir. The volume weight adjustment factors, column 7, table 1, are based on the estimated dry weight of a cubic foot of sediment from a storage type reservoir where the water level is

TABLE 1

SEDIMENT LOAD DATA

Drainage Basin and Stream	Location	Sediment Contrib. Area (sq.mi.)	Length of Record (yrs.)	Measured Annual Sed. Production Rate: Per Sq. Mi. (ac.ft.)	Measured Annual Sed. Production Rate: Est. Vol. Weight Lbs/cu.ft.	Volume Wt. Adj. Factors 1/	Bed Load Adj. Factors	Adj. Ann. Sediment Prod. Rate (a/f/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CANADIAN RIVER									
Wolf Creek	Lipscomb	697	6.94	.531	40	1.00	1.30	.69	16
RED RIVER									
Pease River	Crowell	2,410	5.002	.412	70	1.40	1.30	.75	2
Red River	Denison	32,840	6.260	.415	70	1.40	1.30	.76	2
SABINE RIVER									
Sabine River	Logans-port, La.	4,858	20.156	.131	70	1.17	1.30	.20	2
NECHES RIVER									
Angelina River	Horger-Broaddus	2,803	11.817	.082	70	1.75	1.30	.187	2,21
Neches River	Rockland	3,539	27.118	.080	70	1.75	1.30	.182	2,21
TRINITY RIVER									
Denton Creek	Roanoke	621	4.62	.650	60	1.00	1.10	.71	16
East Fork	Rockwall	840	6.61	.541	35	1.00	1.10	.60	16
Trinity River	Rosser	8,057	3.181	.073	70	1.75	1.15	.15	2
Trinity River	Romayor	17,192	21.142	.198	70	1.75	1.15	.39	2,21

TABLE 1 (Continued)

SEDIMENT LOAD DATA

Drainage Basin and Stream	Location	Sediment Contrib. Area	Length of Record	Measured Annual Sed. Production Rate		Volume Wt. Adj. Factors 1/	Bed Load Adj. Factors	Adj. Ann. Sediment Prod. Rate	References
				Per Sq. Mi.	Est. Vol. Weight				
		(sq.mi.)	(yrs.)	(ac.ft.)	Lbs/cu.ft.			(a/f/sq.mi.)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SAN JACINTO RIVER									
West Fork	Humble-Conroe	1,811	20.753	.103	70	1.75	1.30	.23	2,21
East Fork	Cleveland	330	4.833	.034	70	1.75	1.30	.078	2,21
San Jacinto	Huffman	2,791	6.597	.182	70	1.75	1.15	.35	2
Buffalo Bayou	Houston	362	7.65	.389	60	1.00	1.10	.43	16
Brays Bayon	Houston	100	7.51	.208	60	1.00	1.10	.23	16
White Oak B.	Houston	92	7.43	.580	60	1.00	1.10	.64	16
BRAZOS RIVER									
Salt Fork	Aspermont	2,216	1.238	1.272	70	.875	1.30	1.45	2
Salt Fork	Seymour	5,250	6.107	1.238	70	.875	1.30	1.42	2
Double Mountain Fork	Aspermont	1,510	9.244	1.765	70	.875	1.30	2.01	2
Clear Fork	Crystal Falls	4,320	3.307	.131	70	1.0	1.0	.131	2
Clear Fork	Eliasville	5,740	1.244	.092	70	1.0	1.15	.105	2
Little River	Little River	5,253	4.962	.143	70	2.0	-	.29	2
San Gabriel River	Circleville	602	5.403	.369	70	2.0	-	.74	2
Leon River	Belton-Gatesville	2,313	8.916	.143	70	1.40	1.30	.26	2,21
Navasota River	Easterly	949	12.081	.184	70	1.75	1.15	.37	2
Brazos River	South Bend	12,360	15.710	.259	70	1.37	1.30	.46	2,21

TABLE 1 (Continued)

SEDIMENT LOAD DATA

Drainage Basin and Stream	Location	Sediment Contrib. Area (sq.mi.)	Length of Record (yrs.)	Measured Annual Sed. Production Rate: Per Sq. Mi. (ac.ft.)	Measured Annual Sed. Production Rate: Est. Vol. Weight Lbs/cu.ft.	Volume Wt. Adj. Factors 1/	Bed Load Adj. Factors	Adj. Ann. Sediment Prod. Rate (a/f/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
BRAZOS RIVER (cont'd)									
Brazos River	Mineral Wells	13,910	10.332	.468	70	1.00	1.15	.54	2
Brazos River	Glen Rose	15,600	4.588	.537	70	1.00	1.15	.62	2
Brazos River	Waco	19,260	9.254	.536	70	1.00	1.15	.62	2
Brazos River	Richmond	34,810	33.306	.538	70	1.40	1.05	.79	2,21
Big Elm Creek	Buckholtz	166	2.54	2.08	70	1.00	1.05	2.19	16
Big Elm Creek	Temple	68.5	2.29	4.78	50	1.00	1.05	5.02	16
North Elm Creek	Ben Arnold	30.3	2.00	2.00	50	1.00	1.05	2.10	16
Brushy Creek Subwatershed									
J	Riesel	9.16	5.00	1.30	40	1.00	1.00	1.30	16
D	Riesel	1.74	5.00	.98	40	1.00	1.00	.98	16
Y	Riesel	.48	5.00	1.94	40	1.00	1.00	1.94	16
W-1	Riesel	.28	9.00	6.60	40	1.00	1.00	6.60	16
Y-2	Riesel	.20	4.00	1.44	40	1.00	1.00	1.44	16
COLORADO RIVER									
Llano River	Llano	4,000	11.167 2/	.038	70	1.0	1.30	.049	2
Perdernales River	Johnson City	947	11.167 2/	.100	70	1.0	1.30	.130	2
Colorado River	San Saba	18,700	27.055	.161	70	1.40	1.15	.260	2,21

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TABLE 1 (Continued)

SEDIMENT LOAD DATA

Drainage Basin and Stream	Location	Sediment Contrib. Area (sq.mi.)	Length of Record (yrs.)	Measured Annual Sed. Production Rate: Per Sq. Mi. (ac.ft.)	Measured Annual Sed. Production Rate: Est. Vol. Weight Lbs/cu.ft.	Volume Wt. Adj. Factors 1/	Bed Load Adj. Factors	Adj. Ann. Sediment Prod. Rate (a/f/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
COLORADO RIVER (cont'd)									
Colorado River	Tow	19,300	5.162	.174	70	1.40	1.15	.280	2
Colorado River	Columbus-Eagle	29,140	6.997	.202	70	1.40	1.10	.310	2
LAVACA RIVER									
Lavaca River	Edna	887	12.083	.105	70	2.00	1.15	.241	2,21
GUADALUPE RIVER									
Guadalupe River	Spring Branch	1,432	15.748	.077	70	1.00	1.15	.088	2,21
Guadalupe River	Victoria	5,311	9.083	.057	70	1.75	1.15	.113	2
SAN ANTONIO RIVER									
San Antonio	Falls City	2,070	5.967	.069	70	1.75	1.15	.138	2
San Antonio	Goliad	3,918	12.748	.095	70	1.75	1.15	.191	2
NUECES RIVER									
Nueces River	Three Rivers	15,600	25.583	.030	70	2.00	1.10	.066	2
Nueces River	Cotulla	5,260	12.748	.011	70	2.00	1.10	.024	2
RIO GRANDE RIVER									
Rio Grande River	El Paso	29,271	8.0	.0067	66.7	.833	1.20	.0067	1
Rio Grande River	Presidio	66,203	8.0	.0283	66.7	.833	1.20	.0283	1

TABLE 1 (Continued)

SEDIMENT LOAD DATA

Drainage Basin and Stream	Location	Sediment Contrib. Area	Length of Record	Measured Annual Sed. Production Rate: Per Sq. Mi.	Measured Annual Sed. Production Rate: Est. Vol. Weight	Volume Wt. Adj. Factors 1/	Bed Load Adj. Factors	Adj. Ann. Sediment Prod. Rate	References
		(sq.mi.)	(yrs.)	(ac.ft.)	Lbs/cu.ft.			(a/f/sq.mi.)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RIO GRANDE RIVER (cont'd)									
Rio Grande River	Johnsons Ranch	70,715	8.0	.0816	66.7	.833	1.20	.0816	1
Rio Grande River	Agua Verde	82,232	2.0	.0690	66.7	.833	1.20	.0690	1
Rio Grande River	Langtry	84,795	11.0	.0686	66.7	.833	1.20	.0686	1
Rio Grande River	Eagle Pass	130,575	21	.0569	66.7	.833	1.20	.0569	2,1
Rio Grande River	Laredo	135,976	2	.0258	66.7	.833	1.20	.0258	1
Rio Grande River	Roma	157,204	14.184	.080	70	.889	1.20	.0853	2

1/ The sediment cubic foot dry weight values used in computing the volume weight adjustment factors in column 7 can be determined by dividing column 6 by column 7.

2/ Data for Water Year 1951-52 deleted.

TABLE 2

RESERVOIR SEDIMENTATION SURVEY DATA

Reservoir	Nearest Town	Sediment Contrib. Area. (sq.mi.)	Length of Record (yrs.)	Type of Record	Average Dry Weight of Sediment (lbs/cu.ft.)	Average Ann. Sediment Production Rate (ac.ft/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RED RIVER							
Bellevue Reservoir	Bellevue	1.44	50	R[2]/	60[4]/	.67	16
Crook Lake	Paris	49.6	32.8	D[1]/	36.4	.96	37
Gibbons Lake	Paris	1.26	56.3	D[1]/	31.5	1.56	37
Santa Rosa Lake	Vernon	334	18.2	R-r[3]/	52[4]/	.73	16
Texoma Lake	Denison	28,971	6.2	D[1]/	52.1	.784	20
SABINE RIVER							
Grand Saline Reservoir	Grand Saline	2.02	13.25	D[1]/	37.8	.85	16
Wills Point Reservoir	Wills Point	1.75	23.6	D[1]/	60.1	3.07	16
TRINITY RIVER							
Beaton L. (Lower)	Corsicana	.82	54	D[1]/	67.4	2.68	16
Bridgeport Reservoir	Bridgeport	1,033	10.8	R-r[3]/	50[4]/	.80	16
Burke Neck Lake	Corsicana	.54	69	D[1]/	67.4	2.49	16
Clark Lake	Ennis	2.87	55	D[1]/	50[4]/	2.65	16
Dallas Lake	Denton	1,157	10.5		53	1.13	16
Dawson City Lake	Dawson	1.07	18.8		32.9	7.30	36
Eagle Mountain Reservoir	Fort Worth	809	18	R-r[3]/	60[4]/	1.50	16
Erie Lake	Fort Worth	1.01	40	R[2]/	60[4]/	1.68	16
Halbert	Corsicana	8.56	28	D[1]/	67.4	5.77	16
Hubbard City L. (#5)	Hubbard	.10	24	R-r[3]/	35[4]/	3.08	16

TABLE 2 (Continued)

RESERVOIR SEDIMENTATION SURVEY DATA

Reservoir	Nearest Town	Sediment Contribu. Area (sq.mi.)	Length of Record (yrs.)	Type of Record	Average Dry Weight of Sediment (lbs/cu.ft.)	Average Ann. Sediment Production Rate (ac.ft/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TRINITY RIVER (cont'd)							
Kemp City Lake	Kemp	1.42	12.8	R[2]/	50[4]/	4.49	16
Kerens City Lake	Kerens	6.28	18.8	D[1]/	54.49	.70	16
Mabank City Lake	Mabank	.33	13	R[2]/	40[4]/	5.65	16
Magnolia Lake	Corsicana	.43	64	D[1]/	35[4]/	3.60	16
Mountain Creek Reservoir	Dallas	274.4	9.7	D[1]/	40[4]/	4.12	16
Murphy Lake	Crandall	3.98	16.5	R-r[3]/	40[4]/	4.33	16
Odell Lake	Hubbard	.55	24	R-r[3]/	40[4]/	1.80	16
Terrell City Lake	Terrell	8.71	28.25	D[1]/	59.2	2.59	16
T & P Reservoir	Weatherford	6.18	8.5	D[1]/	61	.84	16
Variety Club Lake	Bedford	.29	7.8	R-r[3]/	60[4]/	2.41	16
White Rock Reservoir	Dallas	97.4	45.9	D[1]/	35.3	1.08	38
Wolf Creek Reservoir	Palestine	2.50	20	R[2]/	60[4]/	.51	16
SAN JACINTO RIVER							
Elkins Lake	Huntsville	3.05	20	R-r[3]/	60[4]/	.75	16
BRAZOS RIVER							
Abilene Lake	Abilene	97.5	27	D[1]/	60[4]/	.22	16
Eanes Lake	Comanche	13.6	20.3	D[1]/	45	.34	16
Eddleman	Graham	41.4	25.3	D[1]/	49.2	.66	16
Fort Phantom Hill	Abilene	268	14.8	D[1]/	36	.55	16
Hamilton City Lake	Hamilton	11.9	17.8	R[2]/	60[4]/	.26	16
Kirby Lake	Abilene	42.8	13.2	R[2]/	43[4]/	.93	16

TABLE 2 (Continued)

RESERVOIR SEDIMENTATION SURVEY DATA

Reservoir	Nearest Town	Sediment Contrib. Area (sq.mi.)	Length of Record (yrs.)	Type of Record	Average Dry Weight of Sediment (lbs/cu.ft.)	Average Ann. Sediment Production Rate (ac.ft/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BRAZOS RIVER (Continued)							
Meridian Lake	Meridian	3.2	14	R-r[3]/	60[4]/	.72	16
Mineral Wells Lake	Mineral Wells	73.4	19.5	R[2]	60[4]/	1.24	16
Possum Kingdom Lake	Graford	12,955	7.75	R-r[3]/	60[4]/	.58	17
Rogers Lake	Rogers	.51	12	D[1]/	40[4]/	6.31	16
Sweetwater Lake	Sweetwater	108.8	11.8	R[1]/	44[4]/	.41	16
Throckmorton Lake	Throckmorton	11.54	35.7	D[1]/	31.55	.30	16
Waco Lake	Waco	1,662	17.7	D[1]/	58.5	.81	16
COLORADO RIVER							
Brownwood Lake	Brownwood	1,532	16.1	R-r[3]/	40	.48	18
Buchanan Reservoir	Burnet	19,313	3.7	R-r[3]/	60[4]/	.21	18
Buffalo (Knox) Tank	Burkett	1.71	41	R[2]/	60[4]/	.065	16
Coleman City Lake (Old)	Coleman	.69	33.6	R-r[3]/	60[4]/	.68	16
Helms Tank	Llano	.14	25	R[2]/	60[4]/	.13	16
Hollingsworth Pond	Burkett	2.58	3.7	R[2]/	43[4]/	.80	16
Lawn Lake	Lawn	12.8	30	R-r[3]/	43[4]/	.48	16
Philpeco Lake	Pioneer	9.0	15.9	R[2]/	60[4]/	.08	16
Merritt Lake	Goldthwaite	11.5	23	D[1]/	43	.42	16
Miller Lake	San Saba	.38	27.5	R[2]/	60[4]/	.73	16
Moss Ranch Stock Pond (SO)	Llano	.07	32	R[2]/	60[4]/	.073	16
Moss Ranch Stock Pond (WE)	Llano	.19	38	R[2]/	60[4]/	.021	16
Nasworthy Lake	San Angelo	3,119	22.6	D[1]/	67.5	.038	34
Lometa Reservoir	Lometa	4.6	29	R-r[3]/	60[4]/	.21	16
Santa Anna City Lake	Santa Anna	.87	30.5	R-r[3]/	43[4]/	1.34	16

TABLE 2 (Continued)

RESERVOIR SEDIMENTATION SURVEY DATA

Reservoir	Nearest Town	Sediment Contrib. Area. (sq.mi.)	Length of Record (yrs.)	Type of Record	Average Dry Weight of Sediment (lbs/cu.ft.)	Average Ann. Sediment Production Rate (ac.ft/sq.mi.)	References
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
COLORADO RIVER (Continued)							
Santa Anna Lake	Santa Anna	1.05	17	D1/	45.2	1.20	16
Scarborough Lake	Coleman	10.6	17	D1/	51.41	.83	16
Stith Lake	Lawn	1.01	14.6	R2/	52 4/	.65	16
Wall, J.S. Stock Pond	Brady	.35	14	R2/	60 4/	.17	16
White Tank	Brownwood	.80	4.8	R2/	60 4/	.33	16
SAN ANTONIO RIVER							
Medina Lake	San Antonio	578	35.2	D1/	75	.45	16
NUECES RIVER							
Corpus Christi Lake	Mathis	16,791	13.6	D1/	35.6	.066	19
RIO GRANDE RIVER							
Ajuga Reservoir	Toyahvale	43	10	R2/	85 4/	.21	16
Balmohrea Reservoir	Balmorhea	259	8.4	D1/	70 4/	.18	16
Cottonwood Detention	Fabens	2.19	17	D1/	82.4	1.23	16
Rattlesnake Detention	Fabens	2.75	17	D1/	87.8	.46	16
Roberts Detention	Fabens	2.29	17	D1/	78.5	.94	16

1/ Detail Sedimentation Survey.
2/ Reconnaissance Sedimentation Survey.
3/ Range-Reconnaissance Sedimentation Survey.
4/ Estimated.

comparatively uniform and the sediment is not subject to compaction due to alternate wetting and drying.

The adjustment factors for volume weight and bed load are based on the dry weight of sediment samples taken from nearby reservoirs, watershed channel slopes, and the relationship between the texture of sediment source area materials and sediment weights (see ref. 15).

The adjusted average sediment production rate data for each of the land resource areas were plotted against square miles of contributing area to develop the various land resource area sediment production rate indices curves, figures 1 through 5.

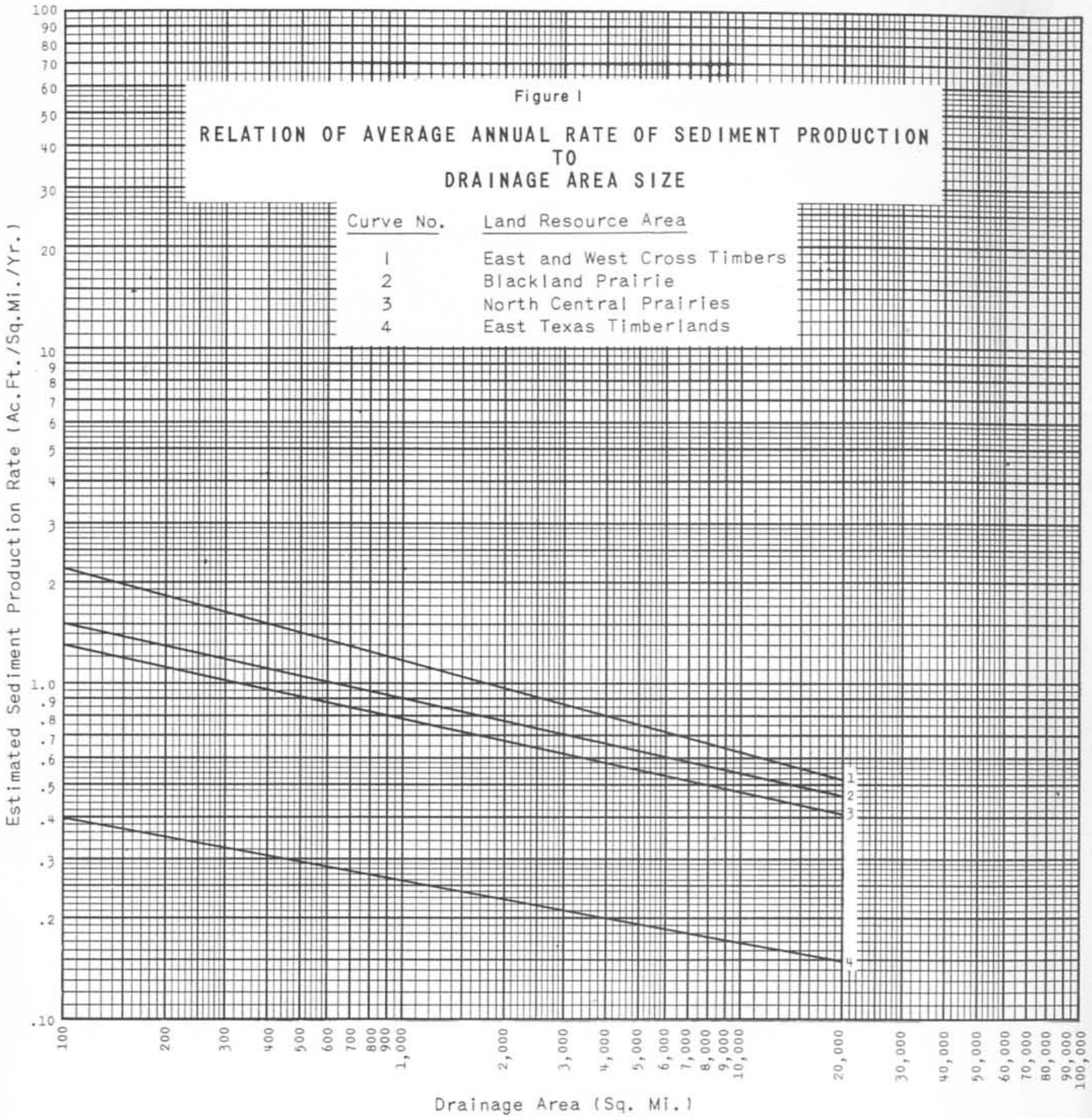
In developing these curves sediment production rate data for watersheds ranging from less than 1 to more than 10,000 square miles in size were used. However, figures 1 through 5 show only the portion of each curve that applies to watersheds with 100 or more square miles of drainage area.

In many cases good to excellent correlations of the two variables were indicated. However, it was necessary, as previously stated, to divide some of the land resource areas into two or more sections and to construct sediment production rate curves for each of these sections before a reasonable correlation between size of sediment-contributing area and the sediment production rate was achieved. For example, due primarily to the wide variations in land use (cover) and sources of sediment, it was necessary to divide the Rolling Plains into three sections in order to establish reasonable uniformity of conditions and construct production rate curves for each section.

The accuracy of the production rate estimates made from the various curves depends principally upon the number and length of the sediment records used in developing the curves and the variations in characteristics of the sample watersheds as compared to the average conditions of the land resource area. Normally, such variations are not great for watersheds over 100 square miles in area. In regard to length of records, sediment records of less than three years in length were given very little weight in estimating rates for the various land resource areas. A relatively small number of samples were used in developing curves number 2 and 3 on figure 4 and curve number 2 on figure 5. Therefore, estimates made from these curves are to be considered as strictly preliminary in nature. All other curves are based on an average of 9 samples per curve and are considered to be suitable for estimating purposes.

Major sub-basin sediment production rates as shown on the map (Plate I) were estimated by using appropriate land resource area sediment production rate curves and the number of square miles of each land resource area in the sub-basin. A sample of the production rate calculations for a sub-basin in the Trinity River watershed will illustrate the procedure used in developing all sub-basin rates.

If only one land resource area is involved, for example sub-basin 7D (Plates I and II), the sediment production rate is read opposite the sub-basin drainage area on the appropriate land resource area sediment production rate indices curve, in this case the Blackland Prairies (figure 1). However, when the sub-basin covers portions of more than one land resource area, for example sub-basin 7A, the sediment production rate curve for each land resource area is used. The following tabulation and narration illustrate the procedure used in developing sediment production rates for this sub-basin:



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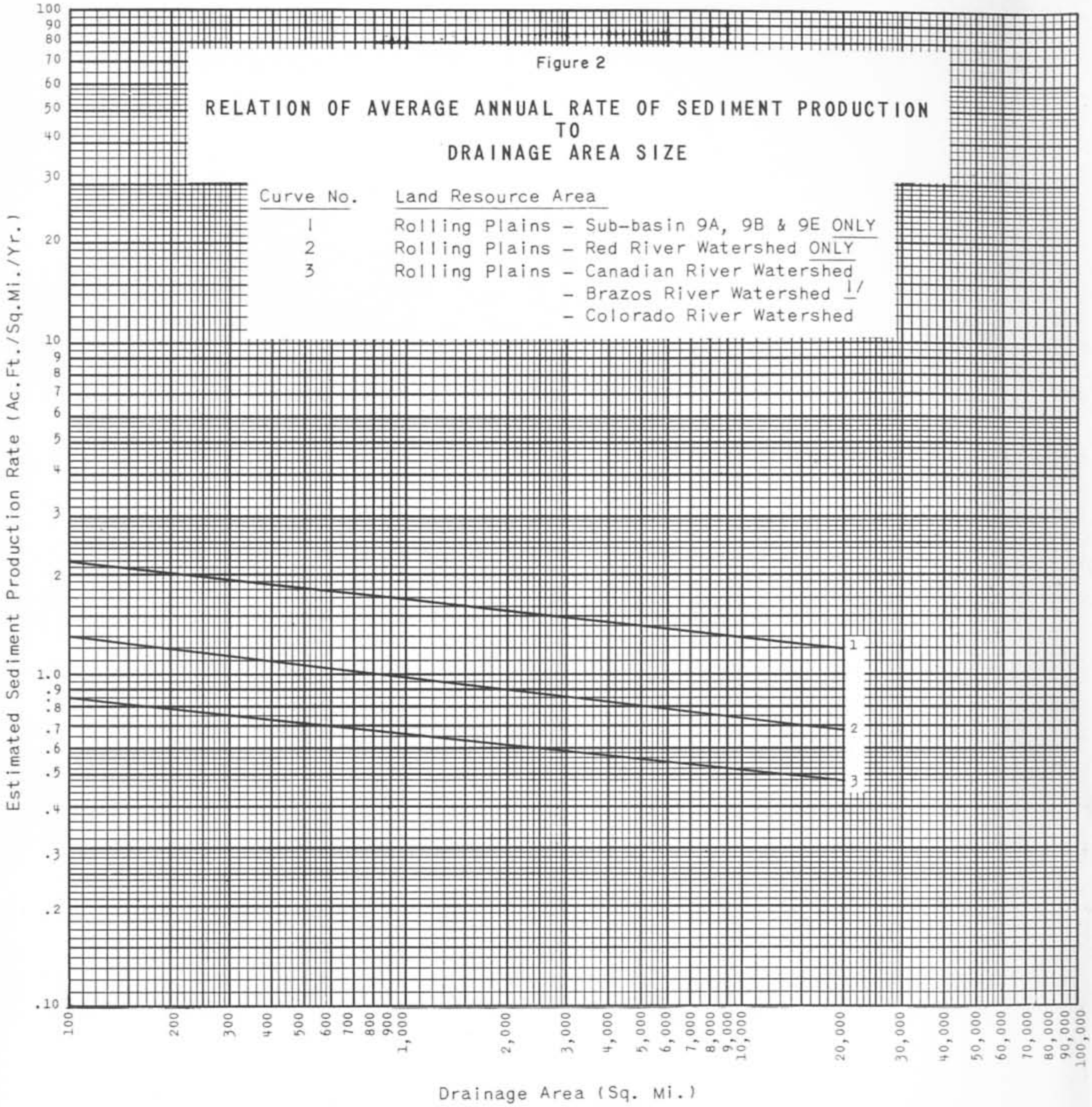
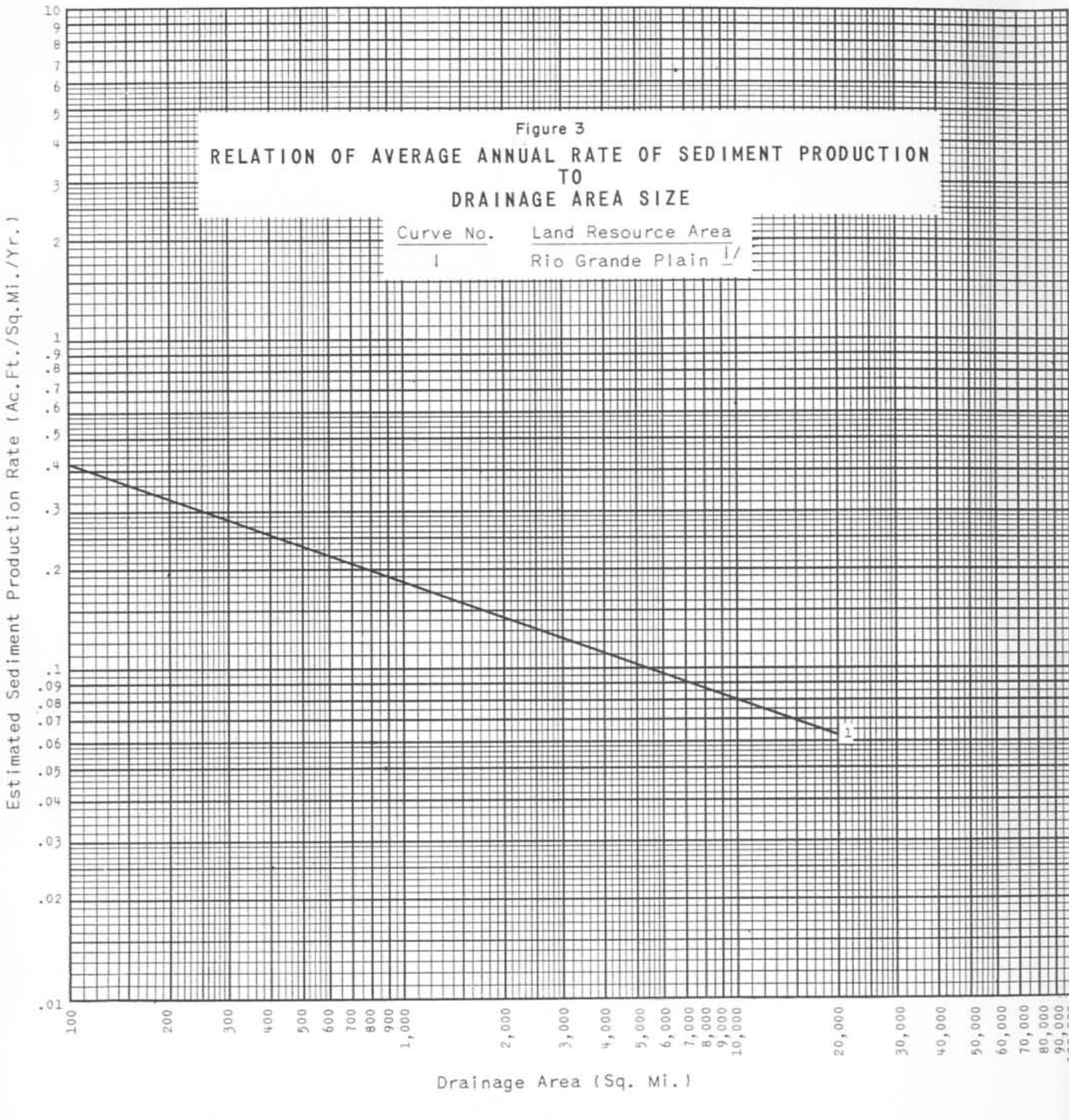


Figure 2

RELATION OF AVERAGE ANNUAL RATE OF SEDIMENT PRODUCTION TO DRAINAGE AREA SIZE

1/ Excluding Sub-Basin - 9A, 9B and 9E



1/ Excluding Rio Grande River drainage and Coastal drainage consisting of Sub-basins 16G, 16H, 16i and 16J.

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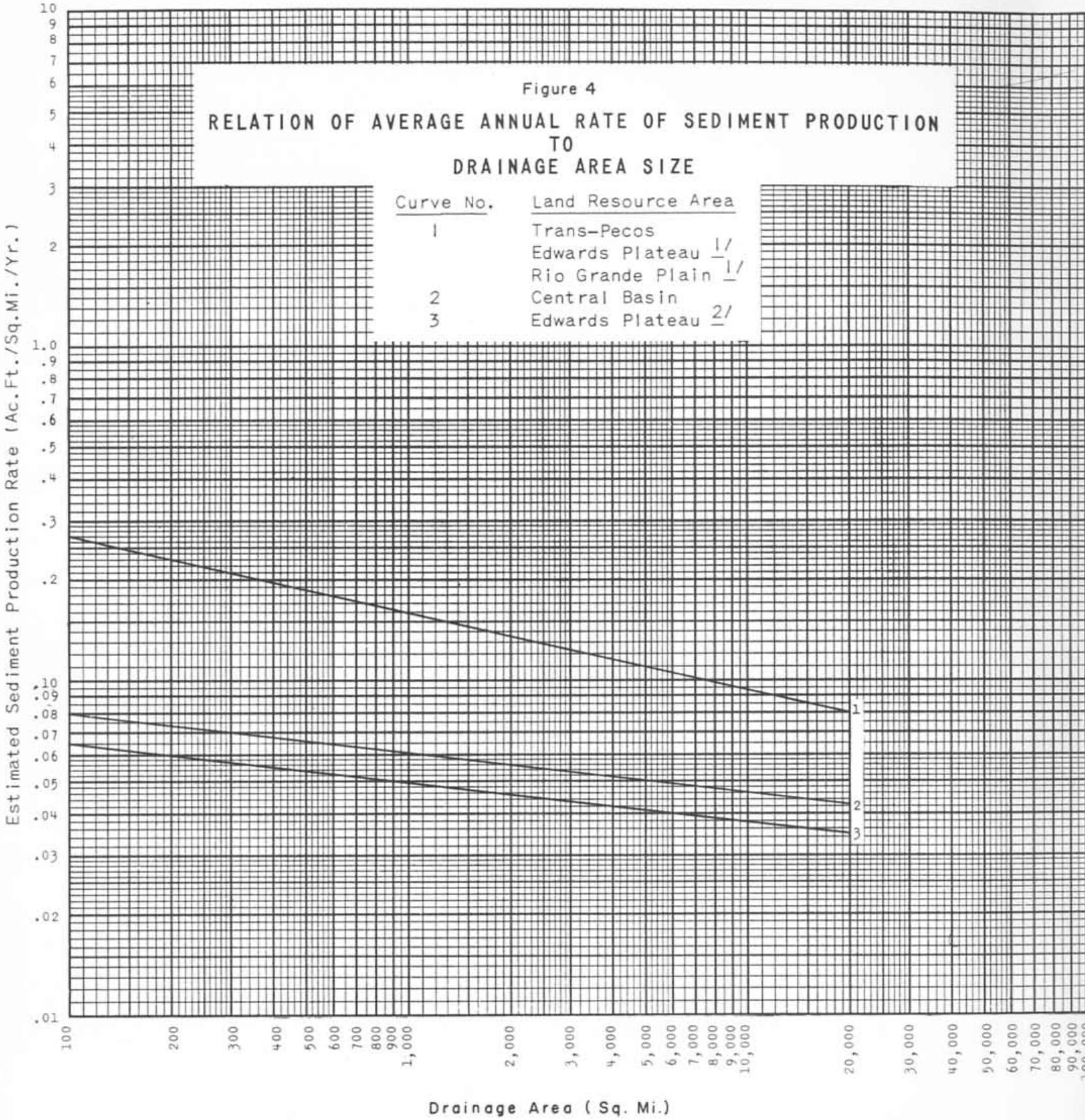
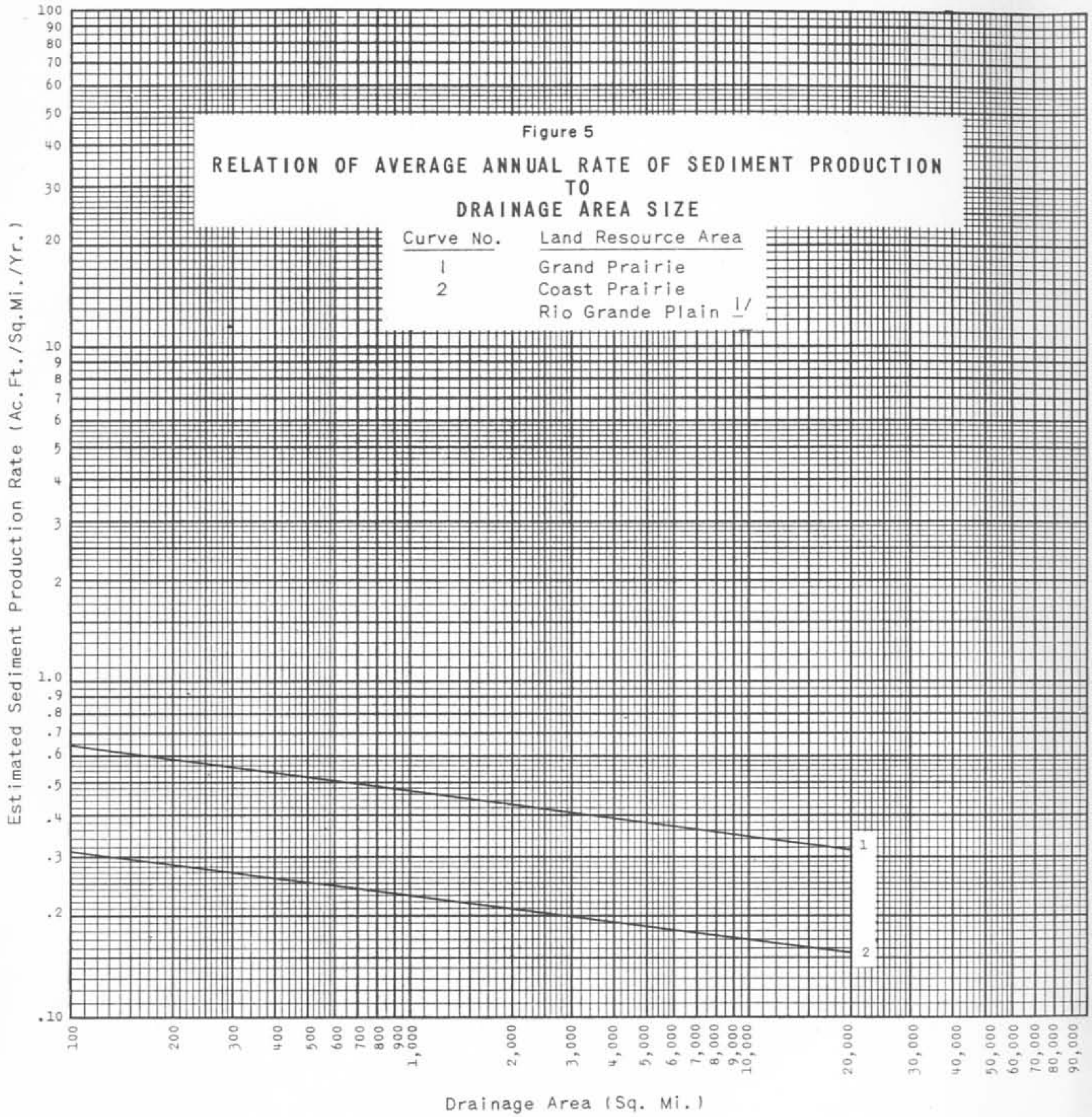


1/ Rio Grande River drainage ONLY
2/ Excluding Rio Grande River drainage



1/ Sub-basins 16G, 16H, 16i and 16J <u>ONLY</u>

Land Resource Area	Land Resource Drainage Area	Total Drainage Area Above Pt. of Estimate	Resource Area Sed. Prod. Rate at the Pt. of Est.	Av. Ann. Volume of Sed. Contributed by ea. Res.Area to Pt. of Est.	Estimated Average Ann. Production Rate for Sub-Basin
	(sq.mi.)	(sq.mi.)	(a.f/sq.mi./yr.)	(ac.ft.)	(a.f./sq.mi.)
(1)	(2)	(3)	(4)	(5)	(6)
No. Central Prairies	1,050	2,627	.65	682.50	
West Cross Timbers	788	1,577	1.01	795.88	0.7
Grand Prairie	789	789	.48	378.72	

The amount of sediment contributed to the point of estimate, by each land resource area and the average annual sediment production rate for the entire sub-basin was estimated in the following manner:

Step 1 - The number of square miles of each land resource area in the sub-basin (column 2 above) was determined. In sub-basin 7A these values were 789, 788 and 1,050 square miles for the Grand Prairie, West Cross Timbers and North Central Prairies land resource areas respectively.

Step 2 - Starting on the main stem drainage at the downstream point of the sub-basin, the total drainage area at the upstream boundary of each land resource area (column 3) was determined. For this sub-basin these values were 789, 1,577 and 2,627 square miles for the Grand Prairie, West Cross Timbers and North Central Prairies, respectively.

Step 3 - The Grand Prairie land resource area sediment production rate curve (figure 5 curve no. 1) at 789 square miles gave the sediment production rate as 0.48 acre-foot per square mile. (Item 3 column 4).

For the West Cross Timbers, on figure 1 curve number 1, the sediment production at 1,577 square miles was read to be 1.01 acre-feet per square miles of drainage area (item 2 column 4). The square mile sediment production rate from figure 1 curve number 3 for a 2,627 square mile watershed in the North Central Prairies was found to be 0.65 acre-foot (item 1 column 4).

Step 4 - The annual volume of sediment contributed by each land resource area (column 5), to the point of estimate, was determined by multiplying the square miles of contributing area (column 2) in each land resource area by the appropriate resource area production rate (column 4).

Step 5 - The total volume of sediment contributed by all land resource areas, divided by the total area of the sub-basin, gave the estimated average annual sediment production rate for the sub-basin (column 6).

Sediment production rates for any point in a watershed or sub-basin can be estimated in a similar manner.

USE AND APPLICATION OF DATA

The information on sediment production rates contained in this report is the best available for planning of reservoir development and sediment control in the various sections of the State.

It also will serve a useful purpose in inter-agency discussion and preliminary project formulation in connection with comprehensive basin planning. Finally it should serve as a means to inform the public at large of both the economic and physical aspects of the sedimentation problem within the State of Texas.

These data will be useful in large-scale preliminary planning of individual or groups of major basins where structural works of improvement, such as large reservoirs, are considered. Preliminary cost estimates may be made relative to sediment storage requirements in large reservoirs, based on the estimates of annual sediment production rates. Tentative locations for such reservoirs can be established with a knowledge of the expected annual damage by sedimentation.

In many cases the reliability of the data is such that final estimates of sediment storage requirements for proposed large reservoirs can be made without further study or analysis.

In areas where no sediment load or reservoir survey measurements have been collected, but estimates of annual sediment production rates are needed for planning purposes, data from similar nearby areas may be used for preliminary estimates. However, if conditions are not uniform, adjustments for such factors as rainfall, runoff, sediment characteristics and land use must be made before a fairly reliable annual rate of sediment production can be established and reservoir life estimated.

Whenever a water-storage project permits a choice of sites for the dam and reservoir basin, careful study should be given to the quantity and type of sediment load that will be produced from the respective drainage basins above the alternate sites. For example, a reservoir site with a watershed area of 1,000 square miles, all of which is located in the Blackland Prairies land resource area would be expected to have an annual sediment production rate of 0.9 acre-foot per square mile of drainage area (figure 1) or 900 acre-feet of sediment inflow each year. If an alternate site had the same watershed area and runoff characteristics but was located entirely within the Grand Prairie land resource area, its expected annual rate of sediment inflow would be only 470 acre-feet, or at the rate of 0.47 acre-foot per square mile (figure 5).

These data also provide approximate or specific information for local, State or Federal agencies, municipalities or individuals concerning the sediment load of a particular stream or the probable rate of annual capacity loss of a specific reservoir. The remaining useful life of a large multiple-purpose reservoir can be predicted if the annual rate of sediment accumulation in such a reservoir has been established by previous reliable sediment load measurements. In addition, estimates of annual maintenance costs on channel improvement works is made possible by a knowledge of the volume and character of sediment load transported by a particular stream.

SEDIMENTATION CHARACTERISTICS OF LAND RESOURCE AREAS IN TEXAS

The State of Texas is divided into 14 major land resource areas based on similarity of soils, topography, climate and vegetation. Listed from east to west, with their approximate areas, these land resource areas are: (See ref. 13.)

Land Resource Area	Acres	Land Resource Area	Acres
East Texas Timberlands	25,000,000	North Central Prairies	6,000,000
Coast Marsh	500,000	Central Basin	2,000,000
Coast Prairie	7,500,000	Rio Grande Plain	22,000,000
Blackland Prairies	11,500,000	Edwards Plateau	22,000,000
East Cross Timbers	1,000,000	Rolling Plains	24,000,000
Grand Prairie	6,500,000	High Plains	20,000,000
West Cross Timbers	3,000,000	Trans-Pecos	18,000,000

Each land resource area differs from the standpoint of physical conditions which influence erosion and sedimentation. A brief description of each with emphasis on factors that affect sediment production follows.

East Texas Timberlands

The East Texas Timberlands have a total area of about 25,000,000 acres. They extend from the Blackland Prairies eastward across the State line, and from the Red River south and southwesterly to the Rio Grande Plain and the Coast Prairie. Elevation ranges from 100 to 600 feet above sea level. The surface relief of the region is uneven, with a general slope from north to south. The land is undulating to rolling and hilly. Average annual rainfall ranges from 50 inches in the southeast to 31 inches in the southwest.

At one time over 25 percent of the East Texas Timberlands was in cultivation, most of which was devoted to row crops. In the past 15 or 20 years a large portion of the cultivated land has been converted to pasture, and this trend is continuing. Between 1949 and 1954 the acreage devoted to pasture doubled while the acreage devoted to cropland decreased by a third (see ref. 18). At the present time approximately 90 percent of the total area of the East Texas Timberlands is either in pasture or woodland, and only 10 percent is in cropland and other uses. This significant change in land use has had a marked effect on sediment production rates and the East Texas Timberlands has changed from a relatively high sediment producing area to one of the lower sediment producing areas of the State.

Annual sediment production rates in watersheds of 1,000 to 5,000 square miles in size are estimated to rage from 0.26 to 0.19 acre-foot per squire mile, and in watersheds of 100 square miles about 0.4 acre-foot per square mile (figure 1).

Sedimentation surveys have been made on six reservoirs ranging in size from 220 to 5,000 acre-feet. Annual sediment production rates in these reservoirs range from 0.08 to 1.71 acre-feet per square mile, and average 0.73 acre-foot per square mile.

Coast Marsh

The Coast Marsh occupies 500,000 acres in the extreme southeast corner of the State. It is composed of saltwater flats and marshes with little if any elevation above tidewaters. The area is flooded by salt water during Gulf storms. It is completely covered with a dense salt water marsh vegetation and is used for grazing as well as for wildlife. Rates of erosion and sediment production in such an area are very low.

Coast Prairie

The Coast Prairie lies along the Gulf of Mexico in southeast Texas and has a total area of about 7,500,000 acres. It is separated from the Gulf by the Coast Marsh at its eastern extremity. With a few exceptions the topography over a wide area appears to be level, but there is a gradual slope toward the Gulf. The maximum elevation above sea level is about 100 feet, but in most of the area it is less than 50 feet. There is an abrupt drop in places of 20 to 30 feet where the Coast Prairie joins the Gulf. Average annual rainfall ranges from nearly 60 inches on the east to 35 inches on the west. The dark heavy clays and sandy loams of the Coast Prairie are used extensively for rice production under irrigation, while most of the remaining area is used for grazing.

There are many small basins and depressions in the area. Streams originating in the Coast Prairie have very shallow and poorly defined channels. Rates of erosion and sediment production are relatively low because of flat topography, low stream gradients and dense vegetative cover.

Since no sedimentation surveys of reservoirs have been made in the Coast Prairie, suspended sediment data were relied on for estimating annual rates of sediment production. These data indicate a maximum annual estimated sediment production rate of about 0.31 acre-foot per square mile for 100 square mile watersheds and 0.23 acre-foot per square mile for 1,000 square mile watersheds (figure 5).

Blackland Prairies

The Blackland Prairies extend in a southwesterly direction, as a broad wedge-shaped area from near Red River in northeast Texas to the vicinity of San Antonio. It is over 300 miles in length and narrows from a width of 75 miles in the northern part to about 15 miles in the southwestern extension. Smaller prairies lie separated but parallel to the main body in southeastern Texas. The Blackland Prairies contain 11,500,000 acres of land which is undulating to gently rolling, and in some places nearly level. Elevations range from 400 to 800 feet above sea level. Average annual rainfall ranges from 30 inches in the southern end to 40 inches in the northeast portion. Nearly two-thirds of all land in the Blackland Prairies is in continuous cultivation. Pastures usually occupy bottomlands and the steep slopes adjacent to them.

The Blackland Prairies have one of the highest average rates of erosion in the State. Severe sheet erosion on the cultivated areas is the major source of sediment. The rate of sediment contribution to streams is high, as the dark clay soils and underlying marls and clays are readily transported by runoff water. Much of the sediment is carried long distances downstream, where it is either deposited in reservoirs or carried on to the Gulf of Mexico.

Overbank deposition in the Blackland Prairies consists of silts and clays produced by erosion of the upland soils. The deposits are low in organic matter and tend to crust and puddle readily. Deposits of this nature adversely affect the tilth and productivity of the soil and result in decreased crop yields. Further damage is caused by deposition of the fine material on growing crops and pasture grasses.

Sedimentation surveys have been made on 24 reservoirs in the Blackland Prairies areas, and suspended sediment samples have been taken periodically at four stations on the Trinity River and its tributaries. Results of these studies indicate a wide variation in sediment production rates. In the 24 reservoir survey, annual sediment production rates were below 1.5 acre-feet per square mile in 4, between 1.5 and 4.0 acre-feet per square mile in 15, and over 4.0 acre-feet per square mile in 5. A study of the suspended sediment samples indicated that the annual sediment production rates on the 15 median reservoirs (rates from 1.5 to 4) were the most reliable. On watersheds 100 to 1,000 square miles in size the estimated annual sediment production rates range from 0.9 to 1.5 acre-feet per square mile; and on watersheds from 1,000 to 10,000 square miles the range is from 0.54 to 0.9 acre-foot per square mile (figure 1).

East Cross Timbers

The East Cross Timbers land resource area occupies about 1,000,000 acres and extends from near Waco northward to the Red River as a strip of land three to ten miles wide. Elevations range between 600 and 800 feet above sea level, and the topography is rolling. Rainfall averages about 35 inches annually. Soils are sandy and easily eroded, and annual sediment production rates are comparable to those of the West Cross Timbers. These rates range from 1.2 acre-feet per square mile for watersheds 1,000 square miles in size to 2.2 acre-feet per square mile for watersheds 100 square miles in size (figure 1). Streams flowing eastward through the East Cross Timbers carry sandy sediment which is often deposited on the more fertile flood plain of the Blackland Prairies, causing serious damage.

Only one lake has been surveyed in the area, the Variety Club Lake northeast of Fort Worth. It is a small reservoir, holding only 33 acre-feet of water, and drains an area of 185 acres. The annual sediment production rate for this watershed has been calculated at 2.40 acre-feet per square mile of drainage area (see ref. 16).

Grand Prairie

This limestone prairie contains 6,500,000 acres, and lies east of the West Cross Timbers. It extends south from the Red River to the vicinity of the Colorado River, where it merges with the Edwards Plateau. On the west small outliers and fingers of the Grand Prairie extend for a distance of 2 or 3 miles into the West Cross Timbers. On the east several knolls of the East Cross Timbers are completely surrounded by the Grand Prairie. Elevations range between 700 and 1,200 feet above sea level, and the topography is generally smoothly rolling, with numerous steep slopes and ridges in the central portion and along the western edge. Average annual rainfall ranges from 32 inches in the western part of the area to 36 inches in the eastern part.

The major portion of the Grand Prairie has a moderately deep soil mantle over limestone rock or broken shaly limestone parent materials. The fine soil texture inhibits free movement of rainfall into the soil, but once the water penetrates to the rock the broken and channeled character of the parent rock gives free movement to ground water.

Most of the deeper soils of the Grande Prairie are in cultivation, but there are large areas of rolling, shallow and gravelly and stony soils used exclusively for the grazing of livestock. About 30 percent of the total land resource area is in cultivation.

Sediment production rates from watersheds entirely within the Grand Prairie are not high, but sandy infertile sediment transported from the West Cross Timbers area is causing widespread damage in tributary flood plains along the western edge of the Grand Prairie. Sedimentation surveys made in 1939 and 1951 on the flood plain of Clear Creek in the Grand Prairie area of Denton County showed a total of 447 acres of additional sandy sediment deposited in the 12-year period. All this sediment originated in the West Cross Timbers but was delivered to the flood plains in the Grand Prairie area. This condition is occurring all along the western edge of the Grand Prairie and poses a serious threat to the remaining sediment-free fertile flood plains of the Grand Prairie. As this sedimentation process continues flooding will increase in frequency and severity, and sandy sediments will be deposited at increasing rates.

In the Grand Prairie, large watersheds of 1,000 to 10,000 square miles are estimated to have annual sediment production rates ranging from 0.47 to 0.35 acre-foot per square mile (figure 5). For watersheds 100 square miles in size the annual rate is estimated at 0.65 acre-foot per square mile.

Sedimentation surveys have been made on a sufficient number of reservoirs in the Grand Prairie to indicate that the rate of sediment production is not high. Rates range from 0.21 acre-foot per square mile in Lometa Reservoir to 1.18 acre-feet per square mile in Lake Dallas. However, the drainage area of Lake Dallas is not entirely within the Grand Prairie. It contains areas of East and West Cross Timbers and some Blackland Prairies, which probably account for the higher rate.

West Cross Timbers

The West Cross Timbers occupies an area about 40 miles wide covering parts of Montague, Wise, Parker, Hood, Erath, Comanche, Callahan and Eastland Counties in the north central part of the State. Its total area is about 3,000,000 acres. Elevations range from 1,000 to 1,800 feet above sea level, and the topography is gently rolling to hilly. The annual rainfall ranges from 25 inches in the western part to 30 inches in the eastern part.

The area is composed of loose, easily eroded, sandy topsoils underlain by sandy clay subsoils. Development of numerous gullies has followed cultivation, and about 60 percent of the farmland has been rendered unfit for cultivation. Heavy deposition of infertile sands has occurred on most of the tributary streams of the area. As a result of this deposition more frequent floods occur, causing channels to become filled. Sediment deposited in the flood plain has greatly reduced fertility, and in many cases has caused a change in land use from row crops to pasture. Damage to roads and bridges is high, as it is necessary to raise both roads and bridges as the sandy deposits bury them.

The West Cross Timbers is one of the major sediment sources in the State. However, due to the heavy weight of the coarse sand particles being transported, the sediment tends to drop close to its point of origin and move slowly downstream as the waters roll it along the stream bed. This has caused swamping of large areas in the flood plain of tributary streams.

Detrimental sandy deposits from the West Cross Timbers have now moved eastward into the Grand Prairie tributary flood plains and are causing considerable damage there.

Annual sediment production rates range from 2.2 acre-feet per square mile in watersheds 100 square miles in size to 1.0 acre-foot per square mile in larger watersheds up to 2,000 square miles in size (figure 1).

Obtaining accurate information on sediment production rates in the West Cross Timbers has been difficult because so few reservoirs have watersheds entirely within this land resource area. The watershed of Eagle Mountain Lake on the West Fork of the Trinity River encompasses three land resource areas: the North Central Prairies, the Grand Prairie and the West Cross Timbers. However, the major portion of the watershed lies in the West Cross Timbers area, and the sediment production rate of 1.50 acre-feet per square mile to this reservoir is thought to be representative of rates for large watersheds in the West Cross Timbers.

North Central Prairies

The North Central Prairies occupy 6,000,000 acres in a wide area extending southward from Clay County on the Red River to Brown County on the Colorado River. The weathering of the sandstones, shales and limestones found in the area has produced a series of discontinuous ridges, valleys, mesas and hills. The relief is generally moderate but in places is featured by high ridges and bluffs, as at Possum Kingdom Lake. Elevations range from about 1,000 to 1,500 feet above sea level. Average annual rainfall ranges from 25 inches on the western edge to 28 inches on the eastern edge. Cultivation is found on about one-fourth of the area, usually in the gently sloping valleys. The other three-fourths of the area is used for the grazing of livestock. Ridges in the rangeland usually are heavily covered with cedar and scrub oak timber.

Annual sediment production rates range from about 0.7 acre-foot per square mile for large drainage areas of around 1,500 square miles to about 1.3 acre-feet per square mile for watersheds 100 square miles in size (figure 1). Most of the sediment produced in the area comes from sheet erosion of cultivated fields.

Sedimentation surveys have been made on seven reservoirs in the North Central Prairies. Annual sediment production rates in these reservoirs range from 0.33 to 1.24 acre-feet per square mile. Lake Mineral Wells, which had the highest annual sediment production rate, drains a portion of the West Cross Timbers, a high sediment-producing area.

Central Basin

The Central Basin, as its name indicates, is in the central part of Texas and occupies some two million acres. Structurally it is a granite dome, but topographyically it is a basin. The surrounding high upland of the Edwards Plateau and the Grand Prairie form a prominent rim around the basin. Elevations in the Basin range from 800 to 1,300 feet above sea level, and the encircling rim lies at an elevation of about 2,000 feet above sea level. The topography of the Basin is rolling to hilly, and in some areas rough and mountainous. Most of the soils in the area have been developed from the disintegration of the exposed granite rock, and usually are very coarse textured. Many areas of shallow soils are found in the Basin, as well as large areas of rough stony land. Most of the land is used for grazing.

Sediment production rates generally are low in this area even on small watersheds. Annual rates range from 0.08 to 0.06 acre-feet per square mile for watersheds of 100 and 1,000 square miles, respectively (figure 4). Much of the sediment in the larger stream channels consists of large grains of silica derived from erosion of the granite. This material moves very slowly as bed load.

Sedimentation surveys have been made on four small ponds in the Central Basin. Results indicate that annual sediment production rates range between 0.07 and 0.17 acre-foot per square miles for small watersheds (see ref. 16). No data are available for large watersheds, but it is estimated that rates are less than 0.05 acre-foot per square mile annually.

The large Buchanan Reservoir is located in the Central Basin, but its watershed is composed of large segments of the Rolling Plains, Edwards Plateau and High Plains, and is not representative of the Central Basin. The measured annual sediment production rate to the reservoir is 0.21 acre-foot per square mile (see ref. 18).

Rio Grande Plain

The Rio Grande Plain occupies the southermost portion of Texas. It consists of a broad, very gently undulating to rolling plain with a general regional slope to the southeast. The total area is about 22,000,000 acres. Elevations range from sea level near the Gulf coast to about 900 feet at the base of the Balcones Escarpment. Average annual rainfall ranges from 33 inches on the east to about 18 inches on the west. Less than one-fifth of the Rio Grange Plain is in cultivation; the remainder is in thorny brush-covered range. The extreme southern part of the area is known as the Lower Rio Grande Valley, or the "Valley." This is an area of irrigated citrus fruits, vegetables, cotton and some feed crops. Dry-land farming in the Rio Grande Plain is limited to the eastern belt near the coast where annual rainfall is over 25 inches. Soils in the Rio Grande Plain vary widely in almost all characteristics, including sediment production. A large area of dark-colored heavy soils covers most of the eastern portion of the Plain, while an area of light-colored sandy soils, including large areas of dune sand, occupies most of the southern portion exclusive of the "Valley". A wedge of brown soils occupies the extreme western portion of the area, and a belt of red sandy soils occupies an area just to the east of the brown soils.

Annual sediment production rates in areas 100 to 1,000 square miles in size range from 0.4 to 0.18 acre-foot per square mile (figure 3). In the rougher portions of the Rio Grande Plain, particularly in the drainage area of the Rio Grande, annual sediment production rates are somewhat lower. Here they range from 0.27 to 0.16 acre-foot per square mile for watersheds 100 to 1,000 square miles in size (figure 4).

The annual sediment deposition rate in the old Corpus Christi reservoir, which drained an area of 16,800 square miles, mostly in the Rio Grande Plain, has been measured at 0.083 acre-foot per square mile in 1942 and at 0.066 acre-foot per square mile in 1948 (see ref. 19). One of the chief reasons for this low rate of sediment production is the low gradient of the Nueces River as it approaches the Gulf. The San Antonio River drains 4,186 square miles, 66 percent of which is from the Rio Grande Plain. Suspended sediment samples taken near the mouth indicate an annual sediment production rate of about 0.15 acre-foot per square mile (see ref. 16). Sediment production rates for other direct Gulf drainage systems in the Rio Grande Plain necessarily must be low because these streams have low gradients. Any appreciable amount of sediment they may have picked up in their headwaters is dropped before they enter the Gulf.

Detailed sedimentation surveys have been made on three small reservoirs in the Rio Grande Plain, and two detailed surveys have been made on the old Lake Corpus Christi. Annual sediment production rates range from 0.066 acre-foot per square mile in old Lake Corpus Christi to 1.89 acre-feet per square mile in the small Smith Pond near Jordanton.

Edwards Plateau

The Edwards Plateau is a high limestone plain in southwest Texas covering an area of about 22,000,000 acres. On the northwest it merges with slightly higher areas of the High Plains, and on the northeast joins the lower lying Rolling Plains in a series of rocky escarpments. On the east it merges with the Grand Prairie with little change in elevation. On the southeast and south the Plateau terminates in steep rocky slopes of the Balcones Escarpment, descending to the level of the Blackland Prairies and Rio Grande Plain. Annual rainfall decreases from 32 inches in the eastern section to 16 inches in the western section. Elevation ranges from 2,000 to 4,000 feet above sea level. Locally there are some nearly level divides and smooth valleys, but generally the area is made up of hilly, broken, and rough lands. Limestone sinks are a feature of the nearly level divides, and these areas are non-contributing so far as sediment is concerned. The Plateau is a large and productive ground water zone, and many large springs issue from caverns around the southern and eastern edges.

The Edwards Plateau is dominantly range land and is used almost exclusively for the raising of livestock. Some cultivation is found on the nearly level divides where deeper soils have developed in the eastern one-third of the area, but less than 5 percent of the total area is in cultivation.

Many streams in the Edwards Plateau are spring fed and are clear flowing most of the time. In times of flood the streams become turbulent and carry a heavy sediment load, much of which is produced by flood plain scour and stream bank erosion. For most of the Edwards Plateau, however, annual sediment production rates are low and have a very narrow range. The estimated average annual rate for 100 square miles is 0.065 and for 10,000 square miles the rate is 0.038 acre-foot per square mile (figure 4). These low rates are due principally to the predominance of native grass cover and the relatively high infiltration capacities of the soils. In the Rio Grande Basin portion of the Edwards Plateau steeper stream gradients apparently cause higher sediment production rates. Here the estimated annual rates in watersheds 100 square miles in size average 0.27 acre-foot per square mile, and in watersheds 10,000 square miles in size about 0.094 acre-foot per square mile (figure 4).

Sedimentation surveys have been made on eight reservoirs ranging in size from 7 acre-feet to 274,065 acre-feet in the Edwards Plateau. Measured annual sediment production rates in these reservoirs range from 0.06 acre-foot per square mile in Lake Nasworthy to 0.45 acre-foot per square mile in Lake Medina.

Rolling Plains

The Rolling Plains land resource area occupies 24,000,000 acres of land in the northwest-central portion of the State. It is bounded on the west by the High Plains, on the south by Edwards Plateau, and on the east by the North Central Prairies and West Cross Timbers. The Rolling Plains extends northward into Oklahoma and Kansas. Elevations range from 3,000 feet above sea level in the northwestern part to around 1,500 feet in the eastern part. Average annual rainfall in the western portion is around 20 to 21 inches, and it increases eastward to about 28 inches.

Sediment production rates are affected by the great variety of conditions found in the Rolling Plains. The western boundary consists of an escarpment of high relief ranging from 200 to 600 feet. In this area erosion is active as streams continue their effort to cut through the High Plains. In the valleys extending eastward from the Cap Rock stream channels have accumulated large deposits of sand for many miles.

Large areas of rough broken land occur in many sections of the Rolling Plains, especially near some of the larger streams, while considerable bodies of land on divides are nearly level. Soils vary from tough heavy clays to sands with all the gradations between these two extremes. Wind erosion is quite active in the many sandy cultivated areas scattered throughout the Rolling Plains, while erosion by water is especially severe in the Red Bed sections.

With the great variety of soils, land use, and topography found in the Rolling Plains, sediment production rates tend to vary greatly. Chief factors affecting these rates are (1) the high percent of pasture and range land (70 percent) and (2) the relatively large amount of nearly level farm land (20 percent). Sediment production rates are not low on all the range land because some heavily grazed range land in the Permian Red Beds and some areas of little or no soil development and grass cover contribute substantial amounts of sediment to the streams.

It was necessary to develop three indices of annual sediment production rates in order to fit the different conditions found in the various watersheds of the Rolling Plains. Highest sediment rates are found in the upper reaches of the Brazos River watershed. Annual sediment production rates in this border area range from 1.7 to 2.2 acre-feet per square mile for watersheds of 1,000 and 100 square miles respectively. For the Red River watershed annual sediment production rates range from about 1.0 to 1.3 acre-feet per square mile for the same size watersheds. For the Canadian and Colorado rivers, and the remainder of the Brazos River, lower sediment rates prevail, ranging from 0.65 to 0.85 acre-foot per square mile for watersheds of 1,000 and 100 miles respectively (figure 2).

It is thoroughly emphasized that local conditions influence annual sediment production rates greatly. Sediment production from a predominately grassed watershed naturally will be low, while sediment production from a sandy cultivated watershed will be high.

About 20 reservoir sedimentation surveys have been made in the Rolling Plains. A study of sedimentation rates in these reservoirs indicate three distinct groupings: (1) low, averaging approximately 0.23 acre-foot per square mile annually; (2) medium, averaging approximately 0.77; and (3) high, averaging approximately 1.35 (see ref. 16).

The reservoirs with low sedimentation rates generally receive their runoff from good grassland. Such reservoirs are Buffalo Tank, Spring Lake, Upper Lake, Sweetwater Lake, and Throckmorton Lake. Reservoirs having medium sedimentation rates receive runoff from eroding range land or a combination of range land and rolling cultivated land. Among these reservoirs are Santa Rosa Lake, Kirby Lake, Scarborough Lake, and Old City Lake at Coleman. Reservoirs accumulating sediment at high rates receive runoff from rolling sandy cultivated land. Examples are Lake Pauline, Lake Childress, Brook Hollow Lake, and the Old City Lake at Santa Anna.

High Plains

The High Plains occupy a vast, outstanding plateau in northwest Texas. On the east this plateau is sharply outlined in most places by a steep escarpment descending to bordering areas of the Rolling Plains. To the south the High Plains merge with the Edwards Plateau through gently descending slopes which rarely assume well defined escarpments. The High Plains include all or parts of 46 counties and comprise a total area of about 20,000,000 acres. Elevations above sea level range from about 3,000 feet in the southeastern part to around 4,500 feet in the northwestern part. The surface appears almost level, but it has a very uniform slope from northwest to southeast which averages 10 to 15 feet per mile. The very nearly level surface is pitted with many small depression lakes which receive nearly all the runoff from the area. Average annual rainfall ranges from 15 inches in the west to 21 inches in the east. All of the High Plains is open land, with about 60 percent in crop use.

The High Plains is considered to be a non-contributing area except for a very narrow rim on its eastern edge. No large reservoirs exist in the area, chiefly because of lack of sites. Sediment production rates in the High Plains are low, estimated at less than 0.10 acre-foot per square mile.

Trans-Pecos

The Trans-Pecos lies west of the Edwards Plateau in the extreme western portion of the State and is characterized by high, level plains and basins from which rise mountain ranges and isolated mountain peaks (see ref. 18). The surfaces of the almost level basins and plains have elevations ranging from 2,500 to 4,000 feet above sea-level, and the adjacent mountains rise 1,000 to 5,000 feet higher. Average annual rainfall ranges from 8 to 11 inches except in the mountains where it may range up to 20 inches.

Within the Trans-Pecos are found two large closed basins. The largest is the Diablo Bolson, which has an area of about 3,230,000 acres (Plate II). This bolson lies between the Diablo Plateau on the west and the Guadalupe Mountains on the east. Another closed basin lies to the east of the Pecos River and has an area of about 2,000,000 acres. Runoff from these closed basins finds its way into scattered lakes and sinkholes and contributes no sediment to the Rio Grande or Pecos Rivers.

Sediment production rates in the Trans-Pecos are estimated to range from less than 0.10 acre-foot per square mile annually for watersheds 10,000 square miles in size to 0.27 acre-foot per square mile annually for watersheds 100 square miles in size (figure 4). For very small watersheds sediment production rates range from 0.5 to 1.0 acre-feet per square mile annually.

Southeastward from El Paso there are numerous arroyos which originate in the Hueco and Finaly Mountains and which drain directly into the Rio Grande through an irrigated area. Sediment from the arroyos causes severe damage to roads, bridges, railroads, irrigation ditches and irrigated land along the Rio Grande. Sedimentation damages are high due to the degree of land development and consequent high values found in this area and the heavy concentrations of sediment at the arroyo mouths.

A flood control survey party of the Soil Conservation Service estimated that the Pecos River in Texas was receiving sediment at an annual rate of 0.20 acre-foot per square mile of drainage area (see ref. 22).

Sediment deposition in reservoirs varies greatly in the Trans-Pecos area. Complicating the picture is the serious wind erosion problem which exists over a large portion of the area. Wind often fills channels with drifts of sand, much of which is moved downstream as bed load when runoff occurs. This causes small stock ponds to fill rapidly and undoubtedly is one of the reasons for the scarcity of stock ponds in the area.

Sedimentation surveys have been made on six reservoirs in the Trans-Pecos area, ranging in size from 137 to 6,750 acre-feet. Annual sediment production rates in these reservoirs range from 0.045 to 0.46 acre-foot per square mile.

EFFECT OF LAND TREATMENT MEASURES ON SEDIMENT PRODUCTION RATES

Land treatment measures which may be installed on watershed lands and which are effective in reducing erosion and sediment production rates include terracing, contour tillage, strip-cropping, crop rotation, improvement of soil fertility, retirement and revegetation of severely eroded cropland and pasture, and range and woodland improvement practices.

It should be emphasized that even the best conservation program for every acre of land will not eliminate all production of sediment from watersheds.

However, available experimental and observational evidence indicates that, in the principal agricultural areas of Texas, present rates of soil erosion and rates of sediment production could be reduced 50 to 90 percent by intensive land treatment of every acre in a watershed without decreasing the net agricultural income from the land.

Table 3 lists the estimated percentage reductions in rates of annual sediment production expected to be brought about by the application of land treatment measures on watersheds of 100 to 10,000 square miles for each land resource area within the State.

Table 3

Estimated Percentage Reductions in Rates of Sediment Production Due to Land Treatment Measures

Land Resource Area	Land Use Distribution Base				Reduction in Sedimentation Rate
	Cultivated	Pasture	Woodland	Misc.	
	(percent)	(percent)	(percent)	(percent)	(percent)
East Texas Timberlands	10	41	48	1	25
Coast Marsh	0	93	0	7	0
Coast Prairie	39	46	13	2	10
Blackland Prairies	62	30	6	2	40
East Cross Timbers	27	23	50	0	25
Grand Prairie	31	62	4	3	30
West Cross Timbers	51	26	21	2	30
North Central Prairies	28	61	9	2	35
Central Basin	12	87	0	1	20
Rio Grande Plain	15	83	0	2	30
Edwards Plateau	3	94	1	2	20
Rolling Plains	28	69	0	3	35
High Plains	Non Contributing				
Trans-Pecos	9	90	0	1	5

These percentage reductions are based on: (1) untreated conditions and average land use existing in each of the land resource areas as reported in a conservation needs inventory prepared by the Soil Conservation Service in 1949; and (2) the application of 80 percent of the needed land treatment measures maintained at 75 percent effectiveness, with the expectation that this degree of treatment will be accomplished during the next 20 years.

In using these reduction estimates in planning reservoir sediment storage capacities, the curves (figures 1-5) are read and the sediment production rate is reduced by the percentage shown for the particular land resource area in question. To establish a rate where more than one land resource area is involved the procedure outlined on pages 24 and 25 is then followed.

SPECIFIC SEDIMENTATION PROBLEMS WITHIN MAJOR BASINS

Watershed No. 1 - Canadian River

The North and South Canadian Rivers in Texas have a combined watershed area of 12,654 square miles; 3,249 square miles of the total are non-contributing (Plates I and II). The watershed of the North Canadian River has about 3,980 square miles in the High Plains and 700 square miles in the Rolling Plains. Wolf Creek, a tributary of the North Canadian River, occupies most of the Rolling Plains in the watershed. In the flood plains of the North Canadian River and its three principal tributaries, Coldwater Creek, Palo Duro Creek and Wolf Creek, over 90 percent of the flood plain is used for grazing. The remainder is used for cultivated crops and hay meadows.

The watershed of the South Canadian River has about 1,200 square miles in the High Plains and 6,770 square miles in the Rolling Plains. Little cultivated land is found on the main stem flood plain, but some of the tributaries in the upper reaches contain as much as 10 percent cultivated land.

The degree of land development is negligible and consequently low values prevail in the watersheds of both the North and South Canadian Rivers. Chief damage by sedimentation is to roads, reservoirs, growing crops and hay meadows.

Special Sediment Problems in the Canadian River Watershed

The main part of the North Canadian River flood plain lies in the High Plains land resource area. The stream has not yet cut through the Ogallala formation to the underlying sandy material, and as a result no sandy deposits of any importance are found in the flood plain. Wolf Creek, a tributary of the North Canadian River, has cut into the sandy material and therefore contains sandy sediment in its flood plain. Wind action has reworked this sandy sediment and has caused some sand dunes to be formed along the flood plain. The valleys of the North Canadian River and its tributaries are not highly developed, and monetary damages by sedimentation are relatively low.

The entire flood plain of the South Canadian River in Texas lies in the Rolling Plains land resource area. The flood plain consists of a narrow band of sandy terrain on each side of the stream bed, which occupies a gorge section in Texas. The stream bed is quite wide compared to the North Canadian River and consists of sandy deposits from the Ogallala formation. Drainage in the stream bed is braided, indicating unstable banks and constantly migrating channels. Tributaries of the South Canadian River are generally choked with sand, especially those in the central and eastern part of the watershed. Wind action has moved great quantities of the sandy sediment in the river bed to adjacent flood plain and upland areas. As a result of this action there are scattered sand dunes on the north side of the river from the Texas-New Mexico State line to the west boundary of Hemphill County. At this point the dunes are about two miles wide and run in a continuous and widening area across Hemphill County to the Texas-Oklahoma State line. Some of the dunes still are active.

Since most of the flood plain of the South Canadian River is in range or meadow, sediment damages by overbank deposition are low.

Sedimentation in Reservoirs

There are no major reservoirs in the Canadian River Basin in Texas, and only three minor recreational reservoirs with a total capacity of about 13,000 acre-feet. There are an estimated 8,927 farm ponds in the Canadian River Basin (see ref. 23). The farm ponds have a total capacity of 45,045 acre-feet, and are losing capacity at an estimated rate of 928 acre-feet annually due to sedimentation.

Watershed No. 2 - Red River

The Red River in Texas, exclusive of the Sulphur River and Cypress Creek, occupies 24,463 square miles, 5,272 of which are non-contributing (Plates I and II). The Red River rises in the High Plains of New Mexico and flows successively through the High Plains of Texas, the Rolling Plains, the North Central Prairies, the West Cross Timbers, the Grand Prairie, the East Cross Timbers, and the East Texas Timberlands. It also receives sediment from the Blackland Prairies through tributaries. The following tabulation lists the land resource areas in the Red River watershed and gives their approximate area:

Land Resource Area	Area in Sq. Mi.	Land Resource Area	Area in Sq. Mi.
High Plains	5,650	Grand Prairie	200
Rolling Plains	14,040	East Cross Timbers	300
N. Central Prairies	1,620	Blackland Prairies	803
West Cross Timbers	150	E. Texas Timberlands	1,700

Annual sediment production rates are lowest in the High Plains and highest in the East and West Cross Timbers, North Central Prairies, Rolling Plains and Blackland Prairies. Moderate sediment production rates prevail in the Grand Prairie, and the East Texas Timberlands.

Special Sediment Problems in the Red River Watershed

The western tributaries of the Red River rising in the High Plains are the North Fork, Salt Fork, Prairie Dog Town Fork, and the Pease River. The drainage pattern is similar in all these tributaries. All originate in the High Plains as shallow swales and flow eastward in broad shallow valleys, deepening gradually. When leaving the High Plains the streams assume very high gradients and plunge in a short distance to the Rolling Plains some five to seven hundred feet below. This has resulted in formation of the Palo Duro Canyon on the Prairie Dog Town Fork, the most conspicuous topographic feature of the Panhandle. It has a depth of 700 feet, and a maximum width of about seven miles.

The flood plains of the western tributaries below the High Plains are completely choked with sand much of which is derived from the sandy deposits of the Ogallala formation underlying the High Plains. The stream beds are relatively wide and the drainage pattern is braided. A significant feature in all the western tributaries below the High Plains, except the Pease River, is the formation of large sand dunes on the south side of the stream beds. Dune formation is greatest on the Prairie Dog Town Fork, and on the main stem of the Red River as far east as Clay County. In the Wilbarger-Wichita area great sand dunes occur on both sides of the Red River. These dunes are one to two miles wide and five to six miles long. Wind erosion is active on portions of these dunes.

During floods all western tributaries have relatively shallow, swift flows and great quantities of sandy sediment move downstream, both as bed load and suspended sediment. Dry periods often cause complete cessation of stream flow, and consequent exposure of wide sandy areas to wind action. The large sand deposits in the western tributaries, as well as the sand dunes, are considered by geologists as normal geologic erosion.

There is almost no cultivation of the flood plains of the western tributaries. A few scattered areas of cropland are found on the Pease River in Cottle and Hardeman counties. Approximately 2,945 acres of flood plain in the western tributaries are receiving crop and pasture damage by overbank deposition (see ref. 18). Most of this damage is in the Pease River system where productivity of the flood plain has been reduced about 25 percent by infertile deposits.

The Wichita River rises in Dickens County and flows through Cottle, Foard, and Knox counties to enter Lake Kemp in Baylor County. The bed of the Wichita River is only slightly sanded, and considerable cultivation is found in the flood plain in the vicinity of Foard County. Below Diversion Lake on the Archer-Baylor County line, and continuing on to the Red River, the Wichita River flood plain is intensively cultivated to irrigated crops. This area receives substantial flood protection from Lake Kemp and Lake Diversion, and sediment damages are negligible.

The Little Wichita River flood plain is relatively free of sandy deposits and is used primarily for grazing of livestock. An estimated 185 acres have received damaging deposits which have reduced fertility 10 percent in the Little Wichita River flood plain. About 270 acres of flood plain land have suffered a 10 to 40 percent loss in productivity due to scour damage.

Six or more minor tributaries enter the Red River below Lake Texoma. Damage due to overbank deposition is occurring on about 3,100 acres of the flood plains of these tributaries (see ref. 18).

The first significant area of cultivation on the Red River main stem is in Clay County, just above the confluence of Wichita River. In Montague County the flood plain of the Red River begins to widen, and at the upper end of Lake Texoma is about two miles wide. Sediment damage is occurring on about 320 acres of flood plain land in this reach above Denison Dam.

Below Lake Texoma the Red River flood plain widens to about three miles. The flood plain is intensively used, and extensive damages to cropland have been caused by sedimentation in the past. The portion of the Red River flood plain from Denison Dam to the confluence of Blue River is protected from flooding by Lake Texoma, and sedimentation damages are now minor. In the area below Blue River some flooding occurs and some damage by overbank deposition is taking place, but at a much lower rate than formerly as a result of the flood control afforded by the Denison Reservoir. The flood plain of the Red River has widened to six miles where it enters the State of Arkansas, and it is highly developed agriculturally along its entire length from Lake Texoma to this point. An estimated 1,250 acres are being damaged by overbank deposition in this reach (see ref. 24).

Sedimentation of Reservoirs

There are at least 30 reservoirs in the Red River watershed in Texas which had original capacities greater than 100 acre-feet (see ref. 18). Three of these are major reservoirs of over 100,000 acre-feet original capacity; 15 are reservoirs with original capacities ranging from 2,500 acre-feet to 100,000 acre-feet; and the remaining 13 range from 100 to 2,500 acre-feet original capacity. There are an estimated 39,090 farm ponds in the watershed with a total capacity of 138,020 acre-feet (see ref. 23). Total amount of original storage for all types of reservoirs was about 6,887,650 acre-feet.

Sedimentation surveys have been made on eleven of the 30 reservoirs having capacities over 100 acre-feet and on several of the smaller farm ponds. Annual sediment production rates range from a low of 0.34 acre-foot per square mile in Spring Lake near Vernon to 1.75 acre-feet per square mile in Lake Gibbons (see ref. 16).

Lake Texoma, located on the Red River near Denison, is the largest reservoir in the watershed. Its original capacity was 5,859,000 acre-feet, 4,066,300 of which is located in the Red River arm of the lake. This arm of Lake Texoma is receiving sediment at an annual rate of 0.6 acre-foot per square mile of contributing drainage area (see ref. 20). This amounts to an annual sediment deposit of about 12,750 acre-feet, 78 percent (9,950 acre-feet), of which is estimated to be originating in Texas.

An estimate made by the Soil Conservation Service in 1952 indicated a total annual capacity loss of 17,000 acre-feet in the 30 reservoirs over 100 acre-feet in capacity (see ref. 18). A study of farm ponds indicated a total capacity loss of about 3,360 acre-feet annually (see ref. 23). Annual capacity loss in all reservoirs of the Red River in Texas now amounts to about 20,360 acre-feet.

Watershed No. 3 - Sulphur River

The Sulphur River in Texas has a watershed area of 3,558 square miles (Plates I and II). About 60 percent of the watershed or 2,150 square miles, lies in the intensively cultivated Blackland Prairies land resource area. This area is a major source of sediment. For small watersheds (100 square miles or less) annual sediment production rates range from about 1.5 to 4.5 acre-feet per square mile of drainage area. The annual sediment production rate for the 2,150 square miles of Blackland Prairies in the upper part of the Sulphur River watershed is about 0.75 acre-foot per square mile (figure 1).

The East Texas Timberlands occupy about 1,408 square miles in the lower part of the watershed. Annual sediment production rates range from about 0.4 acre-foot per square mile for watersheds 100 square miles in size to 0.26 acre-foot per square mile for larger watersheds up to 1,000 square miles in area (figure 1).

The flood plains of most tributaries of the Sulphur River are cleared and being used for crop and livestock production. As a result of frequent flooding in the tributaries over one-half of the flood plains have been converted from cropland to pasture and meadow. The upper portions of the North and South Sulphur Rivers, White Oak Creek, and Cuthand Creek are well developed agriculturally but the lower portions, as well as the main stem of the Sulphur River through Bowie County, remain in timber. This is due to frequent and prolonged flooding in the lower reaches of these streams.

Special Sediment Problems in the Sulphur River Watershed

Overbank deposition in the Blackland Prairies consists of silts, silty clays, and clays produced by erosion of the upland soils. The deposits are low in organic matter, and crust and puddle readily. Deposits of this nature adversely affect the tilth and productivity of the soil and result in decreased crop yields. Further damage is caused by deposition of the fine materials on growing crops and pasture grasses.

Overbank deposits in the East Texas Timberlands consist of infertile sandy material laid down as natural levees along streams, and as alluvial fans at the mouths of tributaries. Since a large portion of the flood plains of tributary streams in this area consists of grassland, sediment damages are not high. A major factor in reducing sediment production is the trend toward livestock raising and the conversion of eroding upland cropland to pasture.

There are approximately 304,000 acres of flood plain land in the tributaries and main stem of the Sulphur River. Nearly 60 percent, or 176,000 acres, still are in timber. Of the approximately 128,000 acres of open land in the flood plain, about 77,000 acres are in pasture and meadow, and 51,000 acres are in crop use (see ref. 24). It is estimated that overbank deposition of infertile deposits has reduced production on about 26,000 acres of crop and pasture land in the Sulphur River watershed.

Sedimentation in Reservoirs

There are at least nine reservoirs in the Sulphur River watershed which had original capacities over 100 acre-feet. The largest is Texarkana Reservoir on the main stem of Sulphur River with a capacity of 2,654,300 acre-feet (see ref. 25). River Crest Electric Reservoir, an off-stream reservoir in the flood plain of Sulphur River, has a capacity of 7,100 acre-feet. The seven smaller reservoirs have capacities ranging from 140 to 900 acre-feet, with a combined total capacity of 3,064 acre-feet (see ref. 18). It is estimated that these seven reservoirs are suffering a loss of capacity of 43 acre-feet annually. There are approximately 11,873 small farm ponds in the Sulphur River watershed, having a total capacity of 27,300 acre-feet (see ref. 23). These ponds are losing capacity at a rate of about 253 acre-feet per year.

The annual sediment production rate to the Texarkana Reservoir is estimated at 0.50 acre-foot per square mile. Using this rate on the 3,400-square-mile watershed, the estimated annual sediment deposit in the reservoir is 1,700 acre-feet. Sediment deposited at this rate would fill the conservation pool of 143,500 acre-feet in approximately 85.5 years.

No sedimentation surveys have been made of any reservoirs in the Sulphur River watershed. Estimated sedimentation losses in reservoirs were obtained from sedimentation surveys made in similar land resource areas in adjoining watersheds.

Watershed No. 4 - Cypress Creek

The Cypress Creek watershed in Texas occupies 2,812 square miles entirely within the East Texas Timberland land resource area (Plates I and II). The annual sediment production rate for this watershed is estimated to be 0.22 acre-foot per square mile, a rather low rate (figure 1). For watersheds 100 square miles in size, the rate is approximately 0.40 acre-foot per square mile, and for farm ponds, the rate may be as high as 1.0 acre-foot per square mile.

Cultivation of the flood plains in the Cypress Creek watershed is confined almost entirely to the tributaries. Nearly all of the large flood plain of Cypress Creek is still in timber. Frequent and prolonged flooding, along with poorly drained infertile soils, has prevented agricultural development in this valley.

There is a total of 284,290 acres of main stem and tributary flood plain land, 47,900 acres of which is open land (see ref. 24). Much of the cleared flood plain is now in pasture or meadow and does not suffer serious sediment damage.

A study made by the Soil Conservation Service in 1950 revealed sediment damage in the form of overbank deposition on 150 acres in the Cypress Creek main stem, and 502 acres on tributary flood plains (see ref. 18).

Sedimentation in Reservoirs

There are at least eight reservoirs with original capacities in excess of 100 acre-feet in this watershed. Ellison Creek Lake is the largest with 24,628 acre-feet of original storage capacity (see ref. 26). When completed, Ferrells Bridge Reservoir on the main stem of Cypress Creek will have a total capacity of 842,000 acre-feet (see ref. 26). Caddo Lake extends several miles into Texas, but information on the storage capacity in Texas is not available.

The Ellison Creek Reservoir and the seven smaller reservoirs have a total original capacity of 29,087 acre-feet (see ref. 18). An estimated 7,310 farm ponds in the watershed of Cypress Creek have a total combined capacity of 19,660 acre-feet, bringing the total original capacity of all existing reservoirs to 48,747 acre-feet (see ref. 23). The estimated annual capacity loss due to sedimentation in the eight existing reservoirs and the 7,310 farm ponds is 140 acre-feet. No sedimentation surveys have been made in any reservoirs in the Cypress Creek watershed.

Watershed No. 5 - Sabine River

The Sabine River watershed occupies 7,383 square miles in East Texas (Plates I and II). It rises in the Blackland Prairies near Greenville, and flows through the rolling East Texas Timberlands and the Coast Prairie to enter Sabine Lake below Orange.

The Blackland Prairies occupy the upper 800 square miles of the watershed, and constitute the highest sediment-producing area (see ref. 27). The annual sediment production rate for the 800 square miles of Blackland Prairies is about 0.95 acre-foot per square mile of drainage area (figure 1). For smaller watersheds, the rate is much higher.

The East Texas Timberlands occupy 6,513 square miles and the Coast Prairie occupies about 70 square miles in the lower end of the watershed. Annual sediment production rates are not high in the East Texas Timberlands. They range from about 0.18 acre-foot per square mile for a watershed 6,600 square miles in size to 0.40 acre-foot per square mile for a watershed 100 square miles in size (figure 1). Annual sediment production rates for small watersheds in the Coast Prairie are lower than those in the East Texas Timberlands (figure 5).

There are over 600,000 acres of flood plain land in the main stem and tributaries of the Sabine River in Texas. Most of the cultivated flood plain is found in the upper tributaries, such as Caddo Creek, Lake Creek, South Fork and Big Sandy Creek. Cultivation in the other tributary flood plains decreases as the Gulf is approached. About five percent of the main stem flood plain is cultivated land or pasture, and sediment damages are low.

Special Sediment Problems in the Sabine River Watershed

About two-thirds of the Blackland Prairies land resource area in the Sabine River watershed is known as "gray lands". This is a transitional area between the true Blackland Prairies and the East Texas Timberlands. Soils consist of sandy loams and clay loams over heavy compact sandy clays, and stiff, intractable non-calcareous clays. Runoff and soil losses are high, and the resulting sediment is low in organic matter and it crusts and puddles readily. A large amount of damage results from smothering of pasture grasses and growing crops.

Annual sediment production rates are low in the East Texas Timberlands because a large percentage of this land resource area is in timber and pasture. Sediment damages are very low in this area because of the lack of agricultural development in the flood plains and the consequent low land values. About 20,000 acres of tributary flood plain land are receiving deposits of infertile overwash which has resulted in decreased crop and pasture yields.

Sedimentation in Reservoirs

There are at least 23 existing reservoirs in the Sabine River watershed which had original capacities greater than 100 acre-feet (see ref. 26 and 27). The largest of these is Lake Cherokee, water supply for Longview, Texas, which had an original capacity of 62,400 acre-feet. The newly constructed Murvaul Reservoir on Murvaul Creek near Carthage has a capacity of 44,650 acre-feet (see ref. 26). Four reservoirs, Greenville Club Lake, Wills Point Reservoir, Grand Saline Reservoir, and Lake Lydia near Quitman, have capacities from 1,000 to 7,000 acre-feet. Their combined total capacity is 14,190 acre-feet. Seventeen other reservoirs have original capacities ranging from 100 to 1,000 acre-feet, and have a combined capacity of 11,576 acre-feet (see ref. 26). There are an estimated 21,630 farm ponds in the Sabine River watershed, having a combined capacity of 52,500 acre-feet (see ref. 23). The existing reservoirs have a total capacity of 185,316 acre-feet.

The Iron Bridge Reservoir is under construction by the Sabine River Authority, and will have a total capcity of 926,000 acre-feet (see ref. 26). When this reservoir is completed, there will be a total storage capacity in all reservoirs in the watershed of 1,111,316 acre-feet.

Sedimentation surveys have been made on three reservoirs in the upper part of the Sabine River watershed. The measured annual sediment production rates for these reservoirs range from 0.82 acre-foot per square mile in Grand Saline reservoir to 3.07 acre-feet per square mile in the Wills Point reservoir.

The estimated annual capacity loss due to sedimentation in the 23 existing reservoirs and the 21,630 farm ponds in the Sabine River watershed is 566 acre-feet (see ref. 18).

Annual loss of storage in the Iron Bridge Reservoir is expected to amount to about 866 acre-feet, based on an estimated annual sediment production rate of 0.9 acre-foot per square mile, and a trap efficiency of 100 percent (see ref. 26). The very low expected capacity loss amounting to only 0.09 percent annually, is due to the high capacity-watershed ratio of 963 acre-feet storage per square mile of drainage area.

Watershed No. 6 - Neches River

The Neches River and its principal tributary, the Angelina River, covers an area of 9,995 square miles in the southeastern part of the State (Plates I and II). The watershed lies entirely within the East Texas Timberlands resource area. The lower 1,745 square miles are in the flatwoods portion of the East Texas Timberlands (see ref. 27).

Annual sediment production rates are moderate to low in the East Texas Timberlands. They range from about 0.17 acre-foot per square mile for a watershed the size of the Neches River (10,000 square miles) to 0.26 acre-foot per square mile for a 1,000 square-mile watershed. Annual rates on watersheds of 100 square miles in size average about 0.4 acre-foot per square mile (figure 1).

There are about 430,000 acres of flood plain in the main stems of the Angelina and Neches Rivers and about 570,000 acres in their tributary flood plains. Very little cultivated land is found on the main stem flood plains, due to frequent and prolonged flooding. Most of the cultivated flood plain land is confined to the smaller tributaries in the upper portion of the watershed. The lower part of the watershed is devoted to commercial and National forests.

Specific Sediment Problems in the Neches River Watershed

Damages due to overbank deposition of infertile sediment are occurring in most of the flood plains of tributaries in the upper portion of the watershed. Sediment delivery rates are high in many small watersheds, but several factors limit the distance the sediment is transported downstream. The high rainfall promotes rapid growth of vegetation, and the flood plains are covered with a dense growth of brush and timber which slows down floodwaters. The large flood plains of the Angelina and Neches Rivers have low stream gradients, and the slow current permits most of the sediment to drop out in upstream reaches. Most of the damage by sediment deposition is confined to smaller streams where tributary channels and a few gullies deposit relatively infertile sediment at the outer edges of the level, densely vegetated flood plains.

A total of 215,000 acres of flood plain in the tributaries of the Neches and Angelina Rivers is subject to floodwater and sediment damage (see ref. 27). An estimated 43,000 acres are being damaged slightly by deposits of infertile sediment (see ref. 27).

Sedimentation in Reservoirs

There are at least 31 reservoirs in the Neches River watersheds which had original capacities exceeding 100 acre-feet (see ref. 26 and 27). The largest of these, Dam "B" on the main stem of the Neches River, had an original capacity of 94,200 acre-feet (see ref. 25). Three municipal water supply reservoirs, Lake Tyler, Gum Creek Reservoir, and Striker Creek Reservoir, have a combined capacity of 102,960 acre-feet (see ref. 26). Twenty-seven smaller reservoirs from 100 to 1,000 acre-feet in size have a combined capacity of 9,250 acre-feet, and 27,657 farm ponds store 74,412 acre-feet of water (see ref. 23). The existing reservoirs have a total capacity of 280,822 acre-feet.

The McGee Bend Reservoir is under construction by the Corps of Engineers and will have a total capacity of 4,040,800 acre-feet (see ref. 25). When this reservoir is completed, there will be a total storage capacity in all the reservoirs in the watershed of over 4,320,000 acre-feet.

No reservoir sedimentation surveys have been made in the Neches River watershed. However, a sufficient number of surveys have been made in adjoining watersheds so that reasonable estimates of sediment production rates can be made.

It is estimated that 744 acre-feet of sediment per year will be deposited in McGee Bend Reservoir. This estimate is based on an annual sediment production rate of 0.21 acre-foot per square mile from a drainage area of 3,453 square miles, and a trap efficiency of 100 percent for the reservoir. For the Rockland Reservoir, with a watershed area of 3,550 square miles, the anticipated capacity loss due to sedimentation is 746 acre-feet annually. With the two structures above Dam "B" having high trap efficiencies, sediment deposited in the reservoir behind Dam "B" would be of minor importance.

The three medium-sized municipal reservoirs, Lake Tyler, Striker Creek Reservoir, and Gum Creek Reservoir, are losing capacity at an estimated rate of 103 acre-feet per year (see ref. 18).

The 27 small reservoirs having a total storage of 9,250 acre-feet are losing capacity at an estimated rate of 652 acre-feet per year (see ref. 27). The 27,657 farm ponds in this watershed are losing capacity at a rate of about 3,872 acre-feet per year (see ref. 23).

For all existing reservoirs, except Dam "B" and possibly other small ones not tabulated, the total annual capacity loss is estimated at 4,627 acre-feet.

Watershed No. 7 - Trinity River

The Trinity River flows successively through seven land resource areas on its was to the Gulf of Mexico (see ref. 28). A tabulation listing these land resource areas and their approximate areas follows: (See ref. 29.)

Land Resource Area	Area in Sq. Mi.	Land Resource Area	Area in Sq. Mi.
North Central Prairies	1,330	Blackland Prairies	6,200
West Cross Timbers	1,140	East Texas Timberlands	6,000
Grand Prairie	2,120	Coast Prairie	215
East Cross Timbers	840	Total Area	17,845

About 35 percent of the Trinity River watershed lies in the highly cultivated Blackland Prairies land resource area. This is a major producer of sediment. For watersheds up to 100 square miles in size, annual sediment production rates range from about 1.5 to 5.0 acre-feet per square mile of drainage area. For larger watersheds the rates usually range from 1.5 acre-feet to about 0.55 acre-foot per square mile. With 6,200 square miles of the watershed in the Blackland Prairies, sedimentation damage to flood plains and reservoirs is of major importance.

Special Sediment Problems in the Trinity River Watershed

A number of tributaries of the Trinity River originate, or flow through, the West Cross Timbers. Such tributaries are Denton Creek, Big Sandy Creek, Clear Creek and Clear Fork. These tributaries receive large quantities of sandy sediment in the West Cross Timbers. The stream beds in the upper reaches of these creeks have been raised several feet by the sandy deposits, causing swamping and reduced channel capacities which results in more frequent flooding. The sandy sediment moves slowly downstream, chiefly as bed load. However, some of it is deposited on the more fertile flood plains of the Grand Prairie, causing further damage.

A somewhat similar situation occurs as tributary streams traversing the East Cross Timbers pick up a load of sandy infertile sediments that are deposited on the fertile tributary flood plains of the Blackland Prairies. However, damage to these flood plains usually is not as great as to those in the Grand Prairie.

The Blackland Prairies furnish great quantities of fine sediment to the Trinity River which is carried downstream in suspension, to be dropped finally in Galveston Bay. This fine material is flocculated as soon as it enters the salt water of the Bay and is deposited near the mouth of the river. As a result, the Trinity River has built a delta out into Galveston Bay covering approximately one thousand acres. The suspended sediment load in the Trinity River at Romayer has been measured at 3,622 acre-feet annually, based on 70 pounds per cubic foot weight of sediment (see ref. 2). Probably another 800 or 900 acre-feet of sediment is carried to the Bay as unmeasured bed load (see ref. 29). Therefore, the total annual sediment being deposited in Galveston Bay from the Trinity River is about 4,500 acre-feet. However recent sediment load measurements indicate the present rate of deposition to be lower than the above rate. This trend can be expected to continue with the further application of more conservation treatment in the watershed, and as more upstream reservoirs are constructed.

The greatest concentration of damaging valley sedimentation occurs in and immediately below the West Cross Timbers land resource area on West Fork, Clear Fork, Elm Fork, and Denton Creek (see ref. 30). Approximately 36,000 acres of cultivated and pasture lands in the alluvial plains of these tributaries have been heavily damaged by sediment deposition. Other sediment-damaged areas are located in the Blackland Prairies.

Sedimentation in Reservoirs

There are 14 reservoirs in the Upper Trinity River watershed which had original capacities greater than 10,000 acre-feet, and approximately 200 reservoirs whose original capacities ranged from 500 to 10,000 acre-feet, including 182 floodwater retarding structures averaging 1,028 acre-feet in capacity (see ref. 26). There are numerous reservoirs less than 500 acre-feet in size, and approximately 61,839 farm ponds with a total capacity of 121,833 acre-feet (see ref. 23).

The largest reservoir, Garza-Little Elm on Elm Fork of the Trinity River has 489,500 acre-feet of conservation and sediment storage and 526,700 acre-feet of flood control storage. The original capacities of all 14 major reservoirs in the Trinity River watershed amount to 2,774,700 acre-feet. Of this amount, 1,222,500 acre-feet is allocated to flood control storage; 1,388,950 acre-feet is for conservation or other storage; and 163,250 acre-feet is in sediment pools (see ref. 26).

Capacities of the 14 major reservoirs, the 28 smaller structures, and the 62,000 farm ponds are being reduced an estimated 10,527 acre-feet annually (see ref. 18 and 23). Sedimentation surveys have been made on 34 reservoirs in the Trinity River watershed. Four of these surveys were on major reservoirs in the Fort Worth - Dallas area. Annual sediment production rates determined by these surveys, expressed in acre-feet per square mile are as follows:

> Bridgeport, 0.80; Eagle Mountain, 1.50; Lake Dallas, 1.18; and White Rock, 1.08 (table 2).

Annual sediment production rates of 28 smaller reservoirs which have been surveyed ranged from a low of 0.64 acre-foot per square mile in Kerens City Lake to 8.3 acre-feet per square mile in the new Kaufman City Lake. The average for all 28 smaller reservoirs was 2.9 acre-feet per square mile.

Watershed No. 8 - San Jacinto River

The headwaters of the San Jacinto River are near Huntsville. The upper watershed is primarily in the East Texas Timberlands, with some small areas of Blackland Prairies included. The watershed below Conroe lies in the "flatwoods" section of the east Texas Timberlands down to the Coast Prairie which begins near the junction of Spring Creek and the San Jacinto River. At this point the watershed narrows abruptly and the river flows through the Coast Prairie into Galveston Bay near Baytown. Buffalo Bayou, Considered as part of the San Jacinto Basin, rises in the western portion of Harris County and flows eastward through the City of Houston to join the San Jacinto River nine miles above Galveston Bay. Its watershed is entirely within the Coast Prairie.

The following land resource areas comprise the San Jacinto River watershed: (See ref. 29.)

Land Resource Area	Area in Square Miles
Blackland Prairies	181
East Texas Timberlands (Upland)	1,565
East Texas Timberlands (Flatwoods)	514
Coast Prairie	1,718
Total Area	3,978

The Blackland Prairies land resource area lies in the northwest portion of the watershed, and though occupying only 181 square miles it furnishes large amounts of fine sediment to the streams. This fine material is carried in suspension downstream and is deposited in Lake Houston. The annual sediment production rate for a watershed of 181 square miles located in the Blackland Prairies is estimated at 1.3 acre-feet per square mile (figure 1).

Annual sediment production rates in the East Texas Timberlands and the Coast Prairie are low, ranging from 0.3 to 0.4 acre-foot per square mile for watersheds 100 square miles in size to 0.17 acre-foot per square mile for watersheds 10,000 square miles in size.

Measurements of suspended sediment load at the Huffman sampling station on the San Jacinto River indicate an annual sediment production rate of 0.24 acre-foot per square mile for the period 1944-48 (see ref. 2). Bed load, estimated at 0.06 acre-foot per square mile, brings the annual sediment production rate to 0.30 acre-foot per square mile.

Special Problems in the San Jacinto Watershed

The most important effect of sediment deposition is in the Houston Ship Channel, in which freshets from the watershed of the San Jacinto River have deposited large quantities of sediment. This sediment is being removed at great expense by the Corps of Engineers. From 1949 to 1956 an average of 3,940,000 cubic yards of material was removed annually from the ship channel (see ref. 25). This was maintenance work over and above dredging in connection with new construction. No estimate is made as to how much of this material is considered as recent sediment, but it is thought to be rather high.

Construction of Lake Houston on the San Jacinto River, and Addicks and Barker Reservoirs on Buffalo Bayou should have a beneficial effect on the Houston Ship Channel sediment problems.

Sediment damage due to overbank deposition of infertile deposits is confined to the small tributaries of the Blackland Prairies and the Rolling East Texas Timberlands in the upper portion of the watershed. It is estimated that over 10,000 acres in the flood plains of these tributaries are being damaged by detrimental deposits.

Sedimentation in Reservoirs

There are three large reservoirs, eleven small reservoirs, and 6,436 farm ponds in the San Jacinto River watershed, storing a total of 600,865 acre-feet of water (see ref. 23, 26 and 30). The two flood control reservoirs, Barker and Addicks, provide 204,800 and 204,500 acre-feet respectively of temporary flood storage (see ref. 25). They operate as dry pool reservoirs and are completely emptied after periods of rainfall. The other large reservoir, Lake Houston, provides municipal and industrial water supply and some degree of flood protection to the area below it. Of the eleven smaller reservoirs, two have capacities over 5,000 acre-feet. These are Sheldon Reservoir, operated by the State Game and Fish Commission with a capacity of 6,950 acre-feet, and Highland Reservoir, constructed by the San Jacinto River Authority, with a capacity of 5,575 acre-feet. The nine remaining small reservoirs have a total capacity of 3,540 acre-feet. The 6,436 farm ponds have a total capacity of 15,510 acre-feet (see ref. 23).

Loss of reservoir capacity in Lake Houston is estimated at 727 acre-feet annually, based on a watershed area of 2,787 square miles, an annual sediment production rate of 0.30 acre-foot per square mile, and a trap efficiency of 87 percent for the reservoir.

The two dry pool reservoirs, Barker and Addicks, each utilize two large uncontrolled conduits during flood flows, as well as three gated conduits, and therefore will by-pass much of the sediment delivered to them. It is believed that the amount of sediment trapped in these two reservoirs will be negligible.

Highlands Reservoir and Sheldon Reservoir are both located in the Coast Prairie, an area of low annual sediment production rates. The amount of sediment trapped in these two reservoirs is believed to be negligible. In the nine other small reservoirs whose total capacity is 3,540 acre-feet, capacity loss due to sedimentation is estimated to be 15 acre-feet annually. The 6,436 farm ponds are losing capacity at an estimated annual rate of 109 acre-feet (see ref. 23).

Sedimentation surveys have been made on two lakes in the Blackland Prairies portion of the watershed. One of these, Elkins Lake, contained 856 acre-feet of storage originally, and has a drainage area of 3.2 square miles. The annual sediment production rate for the watershed of this reservoir is 0.75 acre-feet per square mile (see ref. 16).

Watershed No. 9 - Brazos River

The Brazos River watershed has an area of 42,840 square miles, and receives sediment from ten land resource areas on its course to the Gulf of Mexico. (Plates I and II).

Approximate area in each of the land resource areas is an follows: (See ref. 17.)

Land Resource Area	Area in Sq. Mi.	Land Resource Area	Area in Sq. Mi.
High Plains	7,400	Grand Prairie	8,400
Rolling Plains	8,800	East Cross Timbers	300
Edwards Plateau	1,600	Blackland Prairies	5,000
N. Central Prairies	3,900	E. Texas Timberlands	400
West Cross Timbers	2,000	Coast Prairie	1,000

Annual sediment production rates are relatively low in the High Plains, the Edwards Plateau, the Grand Prairies, and the Coast Prairie, and moderate in the Rolling Plains, the North Central Prairie, and the East Texas Timberlands. However, in the East and West Cross Timbers and the Blackland Prairies, annual sediment production rates are high. Sediment from the East and West Cross Timbers consists of infertile sands which move slowly downstream as bed load. Sediment from the Blackland Prairies consists of clay and silt particles which are readily carried downstream in suspension by the Brazos River and its tributaries.

Special Sediment Problems in the Brazos River Watershed

The Brazos River has seven principal tributaries. Two of these, the salt Fork and Double Mountain Fork, join to form the main stem of the Brazos River at the Haskell-Stonewall County line. Below the confluence of these streams the principal tributaries are Clear Fork, Bosque River, Little River, and Yegua Creek, which enter from the right bank, and the Navasota River which enters from the left bank. Significant damages by sedimentation occur in these tributaries. Damaging valley sedimentation occurs chiefly in the headwaters of the Bosque and Little Rivers, and in Yegua, New Years, Mill, Big, Pond, Aquilla, and Tehuacana Creeks. Major sources of sediment in these streams are the West Cross Timbers and Blackland Prairies land resource areas.

Approximately 129,000 acres of cultivated and pasture lands of the alluvial plains of the Brazos River tributaries have been seriously damaged by sediment deposition (see ref. 17). The distribution of these damaged areas by tributaries is approximately as follows:

Tributary	Area in Acres
Brazos and tributaries above Graham	12,000
Bosque River and tributaries	14,200
Little River and tributaries	29,300
Navasota River and tributaries	12,000
Yegua, New Years, and Mill Creeks	24,000
Big, Pond, Aquilla, and Tehuacana Creeks	25,000
Other minor main stem tributaries	12,500
Total	129,000

Certain reaches in the Bosque River, Little River, Brushy Creek, Tehuacana Creek, Pond Creek, Big Creek, Yegua Creek, Navasota River and Mill Creek, particularly in the upper reaches, have suffered diminished channel capacities as a result of sedimentation, thereby impairing drainage and increasing the frequency and intensity of flooding.

Scouring of farm lands by rapidly flowing floodwaters has seriously damaged an estimated 79,500 acres in the larger cultivated bottomlands of the watershed (see Ref. 17). Scour damage occurs primarily in the flood plains of the Upper Brazos River, the Little River, and the minor main stem tributaries Big, Pond, Aquilla, and Tehuacana Creeks.

Above Graham, bank cutting is permanently destroying an estimated 250 acres annually on the main stem of the Brazos River and its major tributaries, the Salt Fork and Double Mountain Fork (see ref. 17). Below Graham, the Brazos River flood plain is occupied by Possum Kingdom Reservoir for 65 miles. Between the Possum Kingdom dam and Lake Whitney, the Brazos River is deeply entrenched and is confined in a narrow valley having steeply sloped sides. The flood plain is narrow and contains relatively few improvements except for the fish hatchery just below Possum Kingdom Dam. Damages by sedimentation, scour and bank cutting in this reach are of little consequence at the present time.

Below Waco, the river emerges from the area of rugged topography into the rolling Blackland Prairies and the river valley becomes wide and flat. The river follows a winding course below Waco, and its length is about twice the length of the axis of the valley. The river banks in this reach are generally unstable and there is considerable loss of land by bank cutting. A study made by the Corps of Engineers indicated a loss of 19,300 acres from 1900 to 1938 or over 500 acres per year (see ref. 31). This loss is not limited to any given location, but is occurring throughout the entire reach below Waco.

Damage by infertile deposition is not serious in the reach of the Brazos River below Waco. Though some deposition is taking place, the sediments are fertile, and therefore cause little or no loss of productivity. The principal damage done by sedimentation results from smothering of pasture grasses and growing crops.

In general, damage by scouring is not high in the flood plain of the Brazos below Waco. This is due to the low gradient of the river, which averages less than 1.0 foot per mile in this reach. Floodwaters move slowly as a great sheet, and do not acquire the speed necessary to cause severe scouring. However, some scouring is occurring where tributary streams dump great volumes of floodwaters into the Brazos River in relatively short periods of time. This is especially true at the mouth of Little River near Valley Junction and in the vicinity of Washington where Yegua Creek and the Navasota River enter the Brazos River. Quantitative measurements of damage due to scouring is not available in these area.

Sedimentation of Reservoirs

There are 142 reservoirs in the Brazos River watershed with capacities ranging from a few hundred acre-feet to over 2 million acre-feet, and 93,000 farm ponds having a combined total capacity of 243,160 acre-feet (see ref. 17, 23 and 26). The three Corps of Engineers reservoirs, Lakes Whitney, Belton and Waco (when completed) will have a combined capacity of 3,847,400 acre-feet of storage. Twenty-one reservoirs over 5,000 acre-feet in size have a combined capacity of 1,166,700 acre-feet. These include Possum Kingdom Reservoir (733,800 acre-feet), Lake Fort Phantom Hill (74,310 acre-feet), Lake Stamford (60,000 acre-feet), and Lake Cisco (49,100 acre-feet). The 96 reservoirs under 5,000 acre-feet capacity have a total capacity of 85,300 acre-feet. The Soil Conservation Service has constructed 22 floodwater retarding structures having a total capacity of 25,700 acre-feet. Total storage capacity of all reservoirs in the watershed is 5,367,800 acre-feet.

It is estimated that Lakes Whitney, Belton, and Waco (when completed) will be losing capacity due to sedimentation at annual rates of 2,484, 1,117, and 1,052 acre-feet respectively. These estimates are based on annual sediment production rates of 0.67, 0.51, and 0.63 acre-foot per square mile respectively.

The capacity loss in Lake Whitney includes 100 acre-feet of sediment expected to by-pass Possum Kingdom Reservoir.

The 21 non-Federal reservoirs over 5,000 acre-feet in size are losing capacity due to sedimentation at an estimated 10,168 acre-feet annually. The largest of these reservoirs is Possum Kingdom, whose annual capacity loss is 7,384 acre-feet based on an annual sediment production rate of 0.58 acre-foot per square mile (see ref. 17).

The 96 non-Federal reservoirs under 5,000 acre-feet in size are losing capacity at an estimated 290 acre-feet annually and the 93,000 farm ponds are estimated to be losing capacity at a rate of 3,627 acre-feet per year (see ref. 23). The estimated annual capacity loss of all reservoirs in the watershed is 18,738 acre-feet. The above estimates of capacity loss are based on sedimentation surveys of 20 reservoirs in the Brazos River watershed. These reservoirs range in size from 370 acre-feet to 733,800 acre-feet, and are located in 7 different land resource areas. Annual sediment production rates range from 0.15 acre-foot per square mile in the Hamlin Upper Lake (Rolling Plains) to 6.31 acre-feet per square mile in Lake Rogers (Blackland Prairies) (see ref. 16). Surveys from adjoining areas were used to supplement data where needed.

Watershed No. 10 - Colorado River

The Colorado River in Texas has a contributing watershed area of 29,863 square miles. Non-contributing areas in the High Plains and in the western portion of the Concho River watershed total 10,030 square miles (Plates I and II). The Colorado River rises in the High Plains of New Mexico and flows southeasterly through eight other land resource areas before reaching the Gulf. Following is a list of the land resource areas and their approximate area in the Colorado River watershed: (See ref. 32.)

Land Resource Area	Area in Sq. Mi.	Land Resource Area	Area in Sq. Mi.
High Plains	9,800	West Cross Timbers	1,250
Rolling Plains	8,200	Blackland Prairies	1,300
Edwards Plateau	13,500	East Texas Timberlands:	
Grand Prairie	1,060	Upland Area	1,090
Central Basin	2,780	Flatwoods Area	450
		Coast Prairie	463

Annual sediment production rates are low in the High Plains, the Edwards Plateau, the Central Basin, the Grand Prairie, and the Coast Prairie. Annual rates are moderate in the Rolling Plains and the East Texas Timberlands, and high in the West Cross Timbers and Blackland Prairies. Sediment from the West Cross Timbers consists of infertile sandy deposits that usually are deposited close to their origin. Damage from sedimentation is high, locally, but is not important in the overall sediment problem since the West Cross Timbers occupy only 3 percent of the watershed area. Annual sediment production rates vary from 0.9 acre-foot per square mile in watersheds 1,000 square miles in size to 2.2 acre-feet per square mile in watersheds 100 square miles in size. (figure 1.)

The Colorado River flows through two belts of Blackland Prairies, one below Austin and the other below La Grange. Though the belts are small, about

1,300 square miles for the two, the Colorado River receives large quantities of fine sediment as it passes through them. This sediment constitutes a substantial amount of the suspended sediment delivered to the Gulf. The present annual sediment production rate of the Colorado River at Austin is only 0.02 acre-foot per square mile, but at Columbus, after having picked up sediment from the Blackland Prairies and the East Texas Timberlands, the annual sediment production rate has increased 10-fold to 0.202 acre-foot per square mile. The above figures are based on suspended sediment measurements at two sampling stations.

Annual sediment production rates in the Blackland Prairies range from 1.5 to 2.5 acre-feet per square mile in watersheds ranging in size up to 100 square miles (figure 1).

Special Sediment Problems in the Colorado River Watershed

Colorado River Main Stem--

Sediment damages are occurring on the flood plain of the Colorado River from Colorado City to San Saba and from Austin to Eagle Lake. The flood plain from San Saba to Austin is mostly submerged by the reservoirs of Lake Buchanan, Lake Inks, Lake Granite Shoals, Lake Marble Falls, Lake Travis and Lake Austin. The portions not submerged in this reach usually are in gorge sections. The area from Eagle Lake to Wharton has been receiving some measure of flood protection from levees built by local interests, and is not being damaged materially from overbank deposition. The area from Wharton to the mouth floods so frequently that little agricultural development has taken place. Large quantities of sediment are being deposited in the lower end of this section but little damage results because of minor agricultural development.

In the reach from Colorado City to San Saba sandy sediment, derived from cultivated fields and sparsely vegetated ranges of the Rolling Plains is deposited on cultivated crops and grassland in the Colorado River flood plain during periods of overflow. Finer sediments from the area, consisting of red silts and clays from the Permian red beds, are carried into Buchanan reservoir or other lakes downstream. No estimate has been made of the area damaged in this upper reach, or of the annual losses suffered due to sedimentation of flood plains.

The flood plain of the Colorado River from Austin to Eagle Lake varies in width from one-half mile to five miles, and is highly developed agriculturally. Bank cutting has destroyed several thousand acres of fertile flood plain in this reach as infertile sand bars are built on the inside of river bends. Floodwater and sediment damages are high in this reach of the river, but no accurate estimate of the area damaged or the annual monetary loss due to overbank deposition is available.

Sediment from the Colorado River has caused continuous trouble where the River enters Matagorda Bay. A large delta had been built into the Bay by the early 1930's and it soon became apparent that the delta would finally reach the Bay shore of Matagorda Peninsula, and cause the waters of the Colorado River to flow eastward along the Bay side of the Peninsula. This would have caused further widespread sediment deposition within the quiet waters of the Bay. In

1934 a canal was cut through Matagorda Peninsula to direct the flow of the Colorado River directly into the Gulf of Mexico. Since that time the River has built natural levees along both sides completely across the Bay, dividing the Bay into two separate bodies of water.

Sediment deposited by the Colorado River in the channel of the Gulf Intra-coastal Waterway has caused considerable damage. This problem became so severe where the Colorado River and Intra-coastal Canal cross that it was necessary to build locks in order to prevent further sediment damage to the canal.

Colorado River Tributaries--

Work plans have been prepared by the Soil Conservation Service for seven creek watersheds in the authorized Middle Colorado River watershed and for three P. L. 566 watersheds in or near the Colorado River watershed, covering a total area of 4,355 square miles (see ref. 18).

Sediment damages were studied in all 10 watersheds, and were reported on in the work plans. Since these work plans are the only reliable source of information on sediment damages on tributaries of the Colorado River, they were used as samples for expanding to similar areas nearby. Sediment damages by overbank deposition in tributaries above Robert Lee were considered negligible, since there is so little flood plain in cultivation in these tributaries.

Annual sediment damage due to overbank deposition in the tributaries was greatest in the area between Austin and Eagle Lake. On Cummins Creek for instance, sediment damage is occurring on 1,143 acres (see ref. 18). Sediment damages are minor in most of the area above Buchanan Reservoir.

Expansion of work plan data to the tributaries of the Colorado River watershed below Robert Lee indicate a total area of 51,250 acres of flood plain being damaged to some degree by overbank deposition annually and an additional 61,600 acres being damaged by flood plain scour annually. Sediment damage due to swamping is not significant in the tributary flood plains.

Sedimentation in Reservoirs

There are 165 reservoirs in the watershed of the Colorado River which had original capacities over 100 acre-feet (see ref. 26). Sixteen had capacities over 5,000 acre-feet, and four of these had capacities over 100,000 acre-feet. In addition there are 27,186 farm ponds which had total capacity of 94,150 acre-feet (see ref. 23). The total original capacity of all reservoirs in the watershed is approximately 4,204,047 acre-feet.

Sedimentation surveys have been made on 24 reservoirs in the watershed. Size of the reservoirs surveyed ranges from 1.12 acre-feet to 992,500 acre-feet. Surveys were made on Lake Brownwood in 1934, 1940 and 1948, and on Lake Nasworthy in 1938 and 1952. Surveys covered six land resource areas, with the Rolling Plains being best represented with 10 surveys.

The surveys revealed quite a range in annual sediment production rates. In the Rolling Plains rates ranged from 0.065 acre-foot to 1.34 acre-feet per square mile. Three successive surveys of Lake Brownwood indicated an increasing rate of annual sediment accumulation. The annual sediment production rate increased from 0.135 acre-foot in 1934, to 0.38 acre-foot in 1940, to 0.485 acre-foot per square mile in 1948 (see ref. 18). The watershed of Lake Brownwood consists of about two-thirds Rolling Plains and one-third North Central Prairies.

Surveys of Lake Nasworthy made in 1938 and in 1952 showed a declining annual rate of sediment production from 0.04 to 0.03 acre-foot per square mile (see ref. 23). A survey of Lake Buchanan made in 1941 showed a rate of 0.21 acre-foot per square mile from a 20,963 square mile watershed. The annual loss of capacity of this reservoir is 4,400 acre-feet (see ref. 18).

The estimated annual capacity loss in the 16 major reservoirs is 7,936 acre-feet (see ref. 18). The capacity loss of 104 minor reservoirs is estimated at 157.4 acre-feet annually, and the 27,186 farm ponds are estimated to be losing capacity at an annual rate of 1,868 acre-feet (see ref. 23).

Watershed No. 11 - Lavaca River

The area comprising the combined watersheds of the Lavaca River, and its major tributary the Navidad River, lies in the southeastern part of Texas. The streams rise in the Blackland Prairies of Fayette and Lavaca counties and flow through a strip of East Texas Timberlands about 15 miles wide to enter the Coast Prairie. The Blackland Prairies occupy about 916 square miles, the East Texas Timberlands about 693 square miles, and the Coast Prairie about 866 square miles, to form the watershed area of 2,475 square miles (Plates I and II).

Annual sediment production rates are high in the Blackland Prairies and low in the other two land resource areas. Blackland Prairie rates range from 1.50 acre-feet per square mile in watersheds 100 square miles in size to about 0.95 acre-foot per square mile in watersheds 400 to 500 square miles in size (figure 1). The rates are much higher for small watersheds. The annual sediment production rates in the East Texas Timberlands and the Coast Prairie range from 0.3 to 0.4 acre-foot per square mile in watersheds 100 square miles to about 0.25 acre-foot per square mile for watersheds 1,000 square miles in size (figures 1 and 5).

Special Sediment Problems in the Lavaca River Watershed

The Blackland Prairies land resource area is the major source of sediment in the watershed. It occupies the upper 37 percent of the watershed and furnishes large quantities of fine sediment to the streams. Sediment damages are high in the flood plains of the upper portion of the Lavaca and Navidad Rivers and their tributaries.

There are about 66,500 acres in the flood plains of the Lavaca and Navidad Rivers. About 24,000 acres have been cleared and are being used for pasture and cultivated crops, including rice (see ref. 33). An estimated 3,270 acres of this land are damaged 10 to 90 percent annually by sediment deposition.

The Lavaca and Navidad Rivers carry relatively heavy annual sediment loads of 1.10 and 1.04 acre-feet per square mile, respectively, as they enter the East Texas Timberlands. A portion of this sediment is deposited in the timbered flood plains of this area and more is deposited as the streams flow through the low gradient timbered flood plains of the Coast Prairie. Annual sediment production rates are estimated at 0.24 acre-foot per square miles at the mouth of the Navidad River, and 0.25 acre-foot per square mile at the mouth of the Lavaca River.

No sediment damage is being done to the Intra-coastal Canal by the Lavaca River, since most of the sediment entering Lavaca Bay is deposited immediately. The delta built by the Lavaca River covers more than 1,000 acres.

Sedimentation in Reservoirs

No large reservoirs and very few medium size reservoirs are found in the Lavaca River watershed. However, an estimated 7,023 farm ponds are scattered throughout the Blackland Prairies and East Texas Timberlands (see ref. 23). Only 70 farm ponds are estimated to lie in the Coast Prairie portion of this watershed.

The total capacity of the 7,093 farm ponds is estimated at 12,550 acre-feet, and the annual capacity loss is estimated at 154 acre-feet (see ref. 23).

Watershed No. 12 - Guadalupe River

The Guadalupe River rises in Kerr County and flows southeasterly through five land resource areas. It has a total area of 6,033 square miles, (Plates I and II) divided into the following land resource areas: Edwards Plateau, 2,193 square miles; Blackland Prairies, 1,670 square miles; East Texas Timberlands, 1,150 square miles; Rio Grande Plain, 670 square miles; and Coast Prairie, 350 square miles.

Annual sediment production rates are low in the Edwards Plateau, moderate in the Rio Grande Plain, Coast Prairie and East Texas Timberlands, and high in the Blackland Prairies.

Special Sediment Problems in the Guadalupe River

The major source of sediment in the Guadalupe River watershed is from the highly cultivated Blackland Prairies. This land resource area occupies nearly 30 percent of the watershed, and occurs in the two belts 20 to 30 miles wide which lie at right angles to the axis of the river. Tributary flood plains in the area receive large amounts of sediment in times of flooding which choke growing crops and pasture. Scour damage to flood plain lands is also prevalent in this area.

The flood plains of the Guadalupe River and its major tributary, the San Marcos River, are very narrow in the Edwards Plateau portion of the watershed. As the rivers leave the Edwards Plateau through the rough Balcones Escarpment the flood plains widen considerably, and are highly developed agriculturally. Examination of aerial photographs reveals many scour channels and evidence of modern sediment deposition in these main stem flood plains. However, no estimate is available on the number of acres being damaged.

A detailed sedimentation study was made in the Guadalupe River watershed in connection with the development of a work plan for York Creek, a Public Law 566 watershed. This study showed a total of 600 acres of flood plain damaged annually by overbank deposition, and 1,140 acres damaged by scouring (see ref. 39). Using York Creek as a sample and expanding to similar tributary areas, an estimated 6,300 acres are being damaged by overbank deposition, and 11,960 acres are being damaged by scour in the Blackland Prairie tributaries. Using Escondido Creek in the San Antonio River watershed as a sample of the Rio Grande Plain, and expanding to similar watersheds in the Guadalupe River, an estimated 1,710 acres are being damaged by overbank deposition, and 6,030 acres are being damaged by scour in this area. Sediment and scour damage were considered negligible in the Edwards Plateau, the East Texas Timberlands and the Coast Prairie sections.

A study of flood damages in the Guadalupe River was made by the Bureau of Agricultural Economics in 1938 (see ref. 18). This study indicated an annual loss of 238 acres of flood plain by bank cutting. Land damage by swamping is not significant in the watershed.

Sedimentation in Reservoirs

In the Guadalupe River watershed there are no large reservoirs and very few medium-size reservoirs. The Canyon Reservoir is under construction, and will have a total capacity of 749,900 acre-feet when completed (see ref. 25). Annual depletion by sedimentation is expected to amount to approximately 71 acre-feet, based on the watershed area of 1,425 square miles and an annual sediment production rate of 0.05 acre-foot per square mile from the Edwards Plateau. At this rate the capacity allocated to the permanent pool (28,100 acre-feet) would be depleted in a period of about 400 years.

There are four main stem reservoirs on the Guadalupe River which have a combined capacity of about 22,500 acre-feet (see ref. 26 and 40). These low dam, channel-type reservoirs have low trap efficiencies and it is expected that annual capacity loss due to sedimentation is very low.

There are approximately 9,677 farm ponds in the Guadalupe River watershed having a total capacity of 20,029 acre-feet (see ref. 23). It is estimated that these ponds are losing capacity at a rate of 242 acre-feet annually due to sedimentation.

Watershed No. 13 - San Antonio River

The San Antonio River watershed has an area of 4,217 square miles (Plates I and II). It rises in Bandera and Kendall Counties and flows southeasterly through the Edwards Plateau, the Rio Grande Plain, and Coast Prairie land resource areas to join the Guadalupe River about ten miles above San Antonio Bay. The estimated area of each of the land resource areas in the watershed is as follows:

> Edwards Plateau, 1,180 square miles; Rio Grande Plain, 2,772 square miles; Blackland Prairie, 105 square miles; East Texas Timberlands, 130 square miles; and Coast Prairie, 30 square miles.

Annual sediment production rates in the Edwards Plateau portion of the watershed are low, ranging from 0.065 to 0.50 acre-foot per square mile in watersheds 100 to 1,000 square miles in size (figure 4). Rates are somewhat higher in the Rio Grande Plain, ranging from 0.42 to 0.18 acre-foot per square mile in watersheds 100 to 1,000 square miles in size (figure 3). In the Blackland Prairies annual rates are still higher; for the 105 square miles in the watershed the estimated annual sediment production rate is 1.50 acre-feet per square mile (figure 1). Annual sediment production rates are estimated at 0.35 and 0.38 acre-foot per square mile respectively for the 30 square miles of Coast Prairie and the 130 square miles of East Texas Timberlands in the watershed (figures 1 and 5).

Special Sediment Problems in the San Antonio Watershed

A survey report on the San Antonio River was prepared by the Soil Conservation Service in 1952 (see ref. 41). According to this report there are 97,700 acres of flood plain in the tributaries, and 86,000 acres of flood plain along the main stem of the San Antonio River. It is estimated that 21,060 acres of tributary flood plains and 10,090 acres of main stem flood plain are being damaged by overbank deposition to some degree. Scour damage is occurring on an estimated 46,430 acres of tributary flood plain and 28,240 acres of main stem flood plain.

Sedimentation in Reservoirs

Medina Lake is the only large reservoir in the San Antonio River watershed. It had an original capacity of 274,065 acre-feet when constructed. A sedimentation survey of the reservoir in 1948 indicated a total loss in capacity of 8,990 acre-feet in the 35.2 years since construction (see ref. 16). Loss of capacity due to sedimentation in Medina Lake Diversion is insignificant. Sedimentation surveys were made on two recreational lakes in the upper part of the watershed.

Sedimentation conditions were investigated in the Mitchell, Blue Wing, Cassini, Elmendorf and Woodlawn Lakes, all located in Bexar County. Rates of sediment contribution to these reservoirs have been quite low and their annual rates of capacity loss are estimated to be less than 0.5 percent (see ref. 18).

There are approximately 1,560 farm ponds in the San Antonio River watershed with a total capacity of 5,750 acre-feet (see ref. 23). It is estimated that these ponds are losing a total of 86 acre-feet of capacity annually.

Watershed No. 14 - Nueces River

The Nueces River has a watershed area of 16,954 square miles (Plates I and II), 3,504 of which are in the Edwards Plateau. The remaining 13,450 square miles are in the Rio Grande Plain. A study of the Nueces River watershed made by the Soil Conservation Service in 1938 showed less than ten percent of the watershed in cultivation (see ref. 18). Most of the cultivated land is concentrated near the Coast where annual rainfall is over 25 inches. Other small areas of irrigated land are found on the main stem of the Nueces River near Crystal City and Cotulla. There is considerable cultivation in the flood plain of the Nueces River from Three Rivers to the mouth.

The Edwards Plateau portion of the watershed, of which about 96 percent is in native range, is one of the lowest sediment producing areas in the State. Annual sediment production rates in the Rio Grande Plain range from 0.43 to 0.18 acre-foot per square mile in watersheds 100 to 1,000 square miles in size (figure 3). In very small watersheds, such as those above farm ponds, the annual rate may range as high as 2.5 acre-feet per square mile.

The Nueces River rises in the Edwards Plateau at about the 2,400-foot elevation, and descends rapidly to the base of the Balcones Escarpment where the elevation is only about 700 feet. Below the escarpment, it flows generally in an easterly direction with a gradual decrease in stream gradient as the river approaches the Gulf and much of its sediment load is deposited before it enters Lake Corpus Christi.

Special Sediment Problems in the Nueces River Watershed

Sediment damages in the Nueces River are generally low. This is due in part to lack of development in the flood plains of the river and its tributaries, and in part to the naturally low sediment production rates from an area predominately in range and brush.

Investigations were made on the Leona River in Uvalde County and on Lagunillas Creek in Atascosa County in connection with the development of Public Law 566 work plans. The preliminary reports indicated low sediment damages on a small percent of the flood plain land. It is believed this condition exists generally throughout the tributaries of the Nueces River. Since no overall sedimentation surveys have been made in this watershed, no estimate is available of the area damaged by overbank deposition. Indications are that scour damage is much greater than sediment damage in the tributaries of the Nueces River.

Sedimentation in Reservoirs

There are at least 46 reservoirs in the Nueces River watershed with capacities exceeding 100 acre-feet. There are a total of 39 irrigation reservoirs, mostly on the main stem of the Nueces River, having a total capacity of 204,580 acre-feet. These are channel-type reservoirs with low-water dams. Four reservoirs with a total capacity of 300,754 acre-feet are for municipal and industrial water use. One reservoir of 5,400 acre-feet capacity is used in connection with mining activities. The remaining two reservoirs of 110 and 400 acre-feet capacities are used for domestic water supply and recreation, respectively (see ref. 26 and 40).

There are an estimated 2,996 farm ponds in the Nueces River watershed with a total capacity of 19,185 acre-feet (see ref. 18). These ponds are losing capacity due to sedimentation at an estimated rate of 281 acre-feet per year.

Two sedimentation surveys have been made on old Lake Corpus Christi, one in 1942 and the other in 1948. The annual sediment accumulation in the lake decreased from 1,398 acre-feet in 1942 to 1,106 acre-feet in 1948. The rate of annual sediment production for the 16,791 square-mile watershed of old lake Corpus Christi was 0.066 acre-foot per square mile in 1948 (see ref. 19). A new dam has been constructed below the old Corpus Christi dam, and a new reservoir with a capacity of 300,000 acre-feet has been created (see ref. 26). The capacity of the old lake was originally 54,426 acre-feet (see ref. 19).

No estimate is available as to the annual capacity loss in the numerous channel reservoirs on the Nueces River. It is believed that these low-dam reservoirs have a low trap efficiency and therefore are not accumulating sediment at a rapid rate.

Summary

Sediment damages in the Nueces River watershed are generally low. The most important sediment damage in the watershed occurred in old Lake Corpus Christi, where its capacity was being reduced at a rate of about 2 percent per year. Though the annual capacity loss was high, the annual sediment production rate for the watershed was low. This was brought about by the unfavorable ratio of storage capacity to drainage area. This ratio of 3.24 acre-feet of storage per square mile of drainage area was one of the smallest for any major water-supply reservoir in the State. With the construction of the new reservoir this condition was improved materially. The ratio of the storage capacity to drainage area in the new reservoir is nearly 18 acre-feet per square mile, and the capacity loss of 1,106 acre-feet (the same as for the old lake in 1948) is equivalent to only 0.37 percent annually.

Watershed No. 15 - Rio Grande

The Rio Grande Basin has a total drainage area of 48,259 square miles in Texas of which 8,124 square miles are non-contributing (Plates I and II).

The Rio Grande Basin has 29,240 square miles in the Trans-Pecos, 13,415 square miles in the Edwards Plateau, and 5,604 square miles in the Rio Grande Plain land resource areas. Annual sediment production rates in these land resource areas within the Rio Grande Basin are rather low, ranging from 0.27 to 0.16 acre-foot per square mile in watersheds 100 to 1,000 in size (figure 4).

Special Sediment Problems in the Rio Grande Basin

Sediment damages are confined largely to irrigated areas in the Rio Grande Basin. The most severe sediment damages occurring in the watershed are in the area southeast of El Paso where numerous arroyos, originating in the nearby mountains, contribute large quantities of sandy deposits into the Rio Grande. Sediment from the arroyos cause damage to cultivated crops, roads and bridges and other facilities. Sediment deposited in the Rio Grande in this area is removed by the International Boundary and Water Commission in accordance with a treaty that requires maintenance of the river channel to a specified capacity. Work plans have been prepared by the Soil Conservation Service on Diablo and Alamo Arroyos in accordance with Public Law 566. Estimates of material removed annually from the Rio Grande as a result of deposition from the arroyos are 143,035 and 144,335 cubic yards, respectively, according to the work plans. Scour damage is of minor significance in these two watersheds.

There are three other similar arroyos causing damage in this vicinity, and numerous smaller arroyos between Fabens and El Paso causing lesser amounts of sediment damage.

The area between Fort Quitman and Del Rio receives only slight sediment damage because the flood plain of the Rio Grande is relatively narrow and is not highly developed agriculturally. The irrigated section near Presidio, consisting of some 9,300 acres according to the 1950 Irrigation Census, is the exception in this reach of the river. Some sediment damage occurs but the exact area affected is not known.

From Del Rio to the Hidalgo County line there are six areas containing a total of about 60,000 acres of irrigated land along the Rio Grande. There are three watersheds being planned by the Soil Conservation Service near Rio Grande City under Public Law 566. At the present time only preliminary examination reports are available on these three watersheds. These reports indicate about 20 percent of the flood plain has received damage from overbank deposition, with reduction in crop yields of 5 to 20 percent. Scour damage has been moderately high, according to the reports, and channel filling has caused increased flooding. This condition is believed to exist in most of the area below Del Rio.

Work plans have been prepared by the Soil Conservation Service on two Public Law 566 watersheds in the upper reaches of Devils River in the Edwards Plateau land resource area. Annual sediment damages from overbank deposition were estimated to occur on 143 acres in the 5,000-acre flood plain of Johnson's Draw, and scour damage on 774 acres. In the Dry Devils River and Lowrey Draw work plan, sediment damages were estimated to occur on 52 acres and scour damage on 232 acres. These damages are of minor significance, and this condition is expected to exist throughout the Edwards Plateau portion of the watershed.

Sedimentation in Reservoirs

There are about 42 reservoirs in the Rio Grande River watershed with capacities over 100 acre-feet (see ref. 40). Two reservoirs with a total capacity of 21,770 acre-feet are for municipal water supply; three with a total capacity of 1,132 acre-feet, belong to railroads; two, with a total capacity of 12,900 acre-feet are used for power production; and one with a capacity of 150 acre-feet is for domestic water supply. There are 33 irrigation reservoirs with a total capacity of 786,358 acre-feet. The Red Bluff irrigation reservoir had an original capacity of 310,000 acre-feet, but has been losing capacity annually at a rate of 1,600 acre-feet (see ref. 22). Many of the irrigation reservoirs consist of channel-type impoundments with low-water dams. The capacity loss in these reservoirs is low due to low trap efficiency. Falcon Reservoir, with a capacity of 4,150,500 acre-feet, provides flood control and irrigation water for the area below it (see ref. 25). No estimate is made of annual capacity loss due to sedimentation in this reservoir.

Sedimentation surveys have been made on six reservoirs in the Rio Grande Basin in Texas. Annual sediment production rates range from 0.18 acre-foot per square mile in the Balmorhea Reservoir to 1.23 acre-feet per square mile in the Cottonwood detention reservoir (see ref. 16).

There are approximately 2,255 farm ponds in the Rio Grande watershed which have a total capacity of 10,650 acre-feet. It is estimated that these ponds are losing capacity at a total rate of 95 acre-feet annually (see ref. 18).

Watershed No. 16 - Coastal Streams

The Coastal Streams from the Louisiana State line to the San Antonio Bay have a total area of 7,667 square miles, and lie predominately in the Coast Prairie land resource area. The San Bernard and Arenoso Rivers drain small areas of East Texas Timberlands in the upper portions of their watersheds.

The Coastal Streams south of San Antonio Bay have a drainage area of 11,756 square miles and lie in the Rio Grande Plain land resource area. An area containing 4,936 square miles in the southern tip of the State is non-contributing.

Annual sediment production rates in the Rio Grande Plain and Coast Prairie land resource areas in the Coastal Stream area are low, ranging downward from about 0.28 acre-foot per square mile in watersheds 100 square miles in size to 0.23 acre-foot per square mile in watersheds 1,000 square miles in size (figure 5).

Most of the Coast Prairie is in grassland or is being used for rice production. Its nearly level topography and its slowly moving streams tend to keep sediment damages to a minimum.

The Coastal Streams in the Rio Grande Plain section also have low gradients as they approach the Gulf of Mexico, and cause little damage by overbank deposition of infertile sediment.

Work plans have been prepared on four creek watersheds in the Rio Grande Plain portion of the Coastal Stream drainage. By expanding information from these four work plans to other Coastal Streams in the Rio Grande Plain, the following estimates were obtained: 1,430 acres flood plain damaged by overbank deposition and 32,060 acres of flood plain damaged by scour. These estimates emphasize the comparatively low area damaged by sediment as compared to the area damaged by scour.

Sedimentation in Reservoirs

There are about 14 reservoirs in the watersheds of the Coastal Streams having capacities over 100 acre-feet (see ref. 26). Twelve of the reservoirs with a total capacity of 58,080 acre-feet, are used for irrigation, and two reservoirs with a total capacity of 8,990 acre-feet are used for industrial purposes. Since the drainage areas of these reservoirs are small and the annual rate of sediment production is low, loss of capacity due to sedimentation is not a serious problem.

There are an estimated 1,611 farm ponds in the watersheds of the Coastal Streams in the Rio Grande Plain having a total capacity of about 10,159 acre-feet (see ref. 18). These reservoirs are losing capacity due to sedimentation at a total rate of about 138 acre-feet per year. In the Coast Prairie section of the Coastal Streams there are an estimated 613 farm ponds whose total capacity is 2,110 acre-feet. They are losing capacity at an estimated total rate of only 7 acre-feet per year.

Watershed No. 17 - Rio Grande Drainage

This area is located in the southernmost tip of Texas and contains a large part of the irrigated land of the lower valley. Except for urban areas almost all of the 1,777 square miles in this watershed is under irrigation. Flooding in this area was reduced greatly with the construction of Falcon Dam, but the uncontrolled tributaries in Mexico still are capable of flooding the lower-lying areas of the watershed. The Lower Rio Grande Flood Control Project constructed by the United States Section of the International Boundary and Water Commission will furnish further flood protection when the project becomes fully operative.

There are about 500 square miles of bottomland soils in the watershed which constitutes the true delta of the Rio Grande (see ref. 42). This is the area which floods first when the Rio Grande rises, and is the area where considerable damage from scour is occurring. Further damage is caused by the washing out or filling up of irrigation ditches. No estimate is available on areas affected by sediment deposition in this watershed, but it is believed that the area damaged is very small. Considerably more damage is caused by scouring of flood plains than from overbank deposition.

Sedimentation in Reservoirs

There are about 34 reservoirs in the watershed having a total combined capacity of about 246,300 acre-feet (see ref. 40). Thirty-two of these reservoirs with a total capacity of 218,700 acre-feet are used for storage of irrigation water. Most of these irrigation reservoirs are "resacas" or old bends in the river channel later isolated when the river changed its course. Some reservoirs are constructed at a distance from the river channel and are filled by ditches connecting with the river and fed either by gravity flow or by pumping. One reservoir of 26,500 acre-feet capacity (see ref. 40) belongs to the Brownsville Navigation District and is used in connection with the operation of the Intra-coastal Canal which has its beginning in Brownsville. Another reservoir with a capacity of 1,080 acre-feet (see ref. 40) is used for municipal water supply. There are an estimated 220 farm ponds in the watershed with a total capacity of 1,038 acre-feet.

Since water delivered to the reservoirs in the watershed is obtained either from wells or from other irrigation reservoirs such as Falcon, there is very little sediment delivered to the reservoirs, and therefore very slight loss of capacity due to sedimentation is occurring in the structures.

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