Staff Report

AN INVENTORY OF THE SURFACE WATER RESOURCES OF TEXAS

Made for

The Texas Water Resources Committee

By

Robert L. Lowry, Chief Engineer

In collaboration with

The Texas Board of Water Engineers

R. M. Dixon, Chairman
H. A. Beckwith, Member
O. F. Dent, Member

August 1956

TABLE OF CONTENTS

SYNOPSIS

Texas is neither a geographic nor a climatic unit, but rather it is composed of many different kinds of areas. There are four geographic provinces that comprise the State, some of which are so large that the hydrologic conditions of rainfall, evaporation, and run-off vary considerably within the limits of each. The long drainage areas which cross the State from west to east may occupy parts of three different geographic provinces, each differing from the others in climatic and hydrologic characteristics. For example, (1) Rainfall shows a marked variation from an average of more than 55 inches along the eatern border of the State to less than ten inches per year in the arid western regions. (2) Evaporation follows a very similar pattern of distribution to rainfall, but in a reverse order. Net evaporation losses vary from almost zero along the eastern border to as high as 120 inches per year in the Big Bend Area. (3) While run-off is influenced by both rainfall and evaporation the distribution of the run-off in Texas is not a direct function of either of these factors.

The 15-year average total annual run-off from Texas has been 44,150,000 acre-feet. However, during the past 4 years the average was only 22,664,000 acre-feet, which is only about half of the longer average. If two-thirds of this recent run-off could be developed by additional storage facilities it is possible that about 15,000,000 acre-feet might be put to beneficial use.

Total average run-off in Texas for the past 15 years has varied by geographic provinces as follows:

	% of Total Average Annual Run-off of State
Gulf Coastal Plain	78.6%
Central Texas Province	20.2%
Trans-Pecos Texas	1.2%
High Plains	0
	100.0%

During the same period an average of 10,000,000 acre-feet per year has flowed out of Texas into adjoining states. In addition an average of 34,355,000 acre-feet of run-off from Texas has flowed into the Gulf. Of the waters flowing each year into the Gulf, 68.8 percent is contributed by the following stream basins:

	% of Average Annual Run-off into Gulf
Sabine River (Texas only)	16.1%
Neches River	17.7%
Trinity River	18.5%
Brazos River	16.5%
	68.8%

About 3/4 of all the run-off produced in Texas originates from 1/4 of the area of the State, located in East Texas as shown by the map on Figure 23. Rates of run-off are not uniform within this area, but vary from 3 inches on the west side to more than 15 inches along the east side. An equally large area in West Texas furnishes no run-off outside its borders. This area of no run-off is defined on the same map. Between these two extremes there are two intermediate areas which may be considered as fringes of the adjacent areas in-so-far as run-off is concerned.

In the area of West Texas, where no run-off gets beyond its immediate borders, the disposition of local run-off is a purely local problem. Also in East Texas, where most of all run-off in Texas originates, the disposition thereof could in no way influence the High Plains or Trans-Pecos Texas. Since some parts of the State do not contribute to the total run-off and other large areas contribute only a minor amount, it becomes obvious that the problem of surface water in Texas must be approached by considering the areas in which the run-off is produced.

LIST OF CHARTS

LIST OF TABLES

FOREWORD

When the writer became the Chief Engineer of the Texas Water Resources Committee in April 1954, his first and only assignment was to prepare a realistic inventory of the surface water resources of the State. An assistant was provided and work was immediately started. With the knowledge that funds were limited and time would not permit a detailed study of the entire State, two river basins were selected for intensive study, in the hope that they might be used as "guinea pigs" for the whole State. The two streams selected for this treatment were the Brazos and Colorado River Basins.

Although the funds for technical help were exhausted by the end of January 1955, a great deal of additional work has been done since that time, and this report has been prepared.

In covering the assignment an attempt has been made to determine accurately the surface water resources of Texas - where they originate, and where they go. Some of this is limited to an analysis of past records, which reflect only the run-off under historical conditions. Average run-off under present conditions of development is less than the historical run-off. Long-time averages, including the run-off observed many years ago, do not represent the run-off as it is or will be under present watershed conditions, or conditions as they may reasonably be expected to be in the future.

The future run-off can only be projected on the basis of changes in water use which will take place within a given time. Many plans for future development are already known but some are not. Some of these are reflected in the Presentations and Applications for Permits that have been filed with the Board of Water Engineers. Others are possibly more remote, although they have passed the preliminary planning stage but have not been reported. Probably the greatest changes that will be brought about in future water uses are as yet undreamed of. While these possible uses cannot be tabulated, it is important that some allowance be made for them. The net result in respect to the run-off of the future is that a greater part of the water supply now available will be put to use leaving a correspondingly smaller amount of water available for future development.

The maximum utilization of the future water supply of Texas for the welfare of the greatest number of people in the State calls for the full coordination of all agencies, including Federal, State and local interests, who are now involved in planning the development of these water resources.

ACKNOWLEDGMENTS

Many persons and agencies have been helpful in furnishing the material and information upon which this report is based. Without their cooperation it would have been impossible to properly analyze and evaluate the data that of necessity had to be examined.

Among those who have furnished data, as well as help and suggestions are:

U. S. Geological Survey, Surface Water Branch, Texas District,
    Austin, Texas
U. S. Weather Bureau, Austin, Texas
International Boundary and Water Commission, U. S. Section,
    El Paso, Texas
Texas Board of Water Engineers, Austin, Texas
Bureau of Economic Geology, University of Texas, Austin, Texas
Texas Electric Service Company, Fort Worth, Texas

Aside from those who have been mentioned above there are many individuals, too numerous to name, who have been most helpful through their worthwhile suggestions and timely advice.

All of their cooperation is gratefully acknowledged by the writer, with thanks.

Eight of the charts used and referred to in the test were previously prepared for the Texas Electric Service Company, which has graciously permitted their use herein.

Robert L. Lowry, Chief Engineer
Texas Water Resources Committee

Austin, Texas
August, 1956

GEOGRAPHIC PROVINCES OF TEXAS

The structural features of Texas may best be described as the following distinct and different provinces of the State: (1) Gulf Coastal Plain, (2) Central Texas, (3) High Plains, and (4) Trans-Pecos Region. These four subdivisions are outlined approximately on Figure 1, which was taken from Bulletin 3401, The Geology of Texas, Bureau of Economic Geology, 1934, Page 32.

The Texas Gulf Coastal Plain has been described by Sellards[1] as follows:

> "....(it) is a part of a great plain bordering the Atlantic Ocean and the Gulf of Mexico extending from the southern New England states to the Yucatan peninsula in southern Mexico or beyond. This great Coastal Plain is, in fact, a partially submerged, partially emerged, continental shelf ...."

> "....The Texas Coastal Plain is from 150 to 250 miles wide. The land slopes gulfwards, and no part of the region is mountainous, ..."

(1) The most significant feature of the Gulf Coastal Plain is the abrupt change in elevation at the Balcones Escarpment, which locates the line of separation between the Coastal Plain and the Central Texas province, throughout most of its course.

(2) The Balcones Escarpment extends eastward from the Rio Grande near Del Rio to the northern part of Bexar County, and thence north, northeasterly toward the Red River. The largest springs of Texas including, Comal (at New Braunfels), San Marcos (at San Marcos), and Barton Springs (at Austin) emerge along the escarpment.

Continuing the description given by Sellards, [2]

> "The term Central Texas is here used to apply to that part of the state west of the Gulf Coastal Plain, east of Pecos River, and east of the High Plains. Its principal subdivisions are Llano Uplift, Edwards Plateau, Grand Prairie, and Osage Plains regions".

This province includes a large part of the heart of the State, extending generally from the Balcones Escarpment to the Cap Rock, which separates it from the High Plains. Important features are the Llano Uplift and the Edwards Plateau, which are marked by rolling hills and steep slopes.

(3) According to Sellards,[3]

> "The High Plains of Texas include the Panhandle region of the northwest part of the state...."

This entire area, although having a gradual slope to the east, exhibits the appearance of a huge flat plain, on which there are thousands of natural

1 Bulletin 3401, The Geology of Texas, page 33.
2 Bulletin 3401, The Geology of Texas, page 73.
3 Bulletin 3401, The Geology of Texas, page 99.

depressions containing no surface outlets. These depressions, sometimes called playas, collect the surface run-off and hold it until it can seep into the soil, or until it is dissipated by evaporation.

(4) A description of the mountainous territory west of the Pecos River is quoted from Baker [4] as follows:

> "The Trans-Pecos region is properly that which lies between Pecos River and the Rio Grande and includes a large territory in New Mexico as well as in Texas. The region is not all mountainous, since plains extend from Pecos River to the foothills of the mountains, and farther west, lowlands lie between mountain ranges."

These subdivisions of Texas have been given special attention at the beginning of this report because of their significance with respect to run-off, which will be discussed more fully under the heading. In that same connection, the peculiar relation between these geographic provinces and the topography of the State is pointed out, as more fully described in the next chapter.

4 Bulletin 3401, The Geology of Texas, Page 137

TOPOGRAPHY AND DRAINAGE BASINS OF TEXAS

The configuration of Texas is generally that of an inclined plane; with the high side adjoining New Mexico, and the low side meeting the Gulf of Mexico at sea level. There are many irregularities in the slope, however, from one side of the state to another. In central and northwestern Texas two physiographic features have a pronounced effect upon the slopes: the Balcones Escarpment, and the Cap Rock which are, in general, parallel to the Coast. They provide the two most distinct natural boundary lines in Texas. Mountain ranges west of the Pecos River provide the most rugged topography in the State. These mountains constitute the eastern ranges of the Rocky Mountain system. Paradoxically, one of the large flat areas of the State is contained amoung these ranges. This is the lower portion of the Diablo Bolson (the Salt Flats) which lies along the western base of the Guadalupe Mountains.

A generalized contour map of Texas has been prepared from the latest data available to the U. S. Geological Survey, and it is shown as Figure 2. A comparison of this topography with Figure 1, which indicates the Geographic Provinces of Texas, shows that the Gulf Coastal Plain throughout most of its range varies in elevation from zero to 500 feet. Only along the western extremity of the Coastal Plain near the Rio Grande does the elevation range above 500 feet over any appreciable area.

The Central Texas Province varies in elevation from 500 feet to approximately 2,500 feet at the base of the Cap Rock. Differences in elevations along the central portion of the Balcones Excarpment are on the order of 1,500 feet. The Cap Rock brings about a change in topography, with differences in elevations varying along the excarpment from 100 feet to almost 1,000 feet. In general, the Llano Uplift and the Edwards Plateau, which comprise the southern half of this province, are considerably higher in elevation than the Osage Plains and Grand Prairie which form the northern part of this province.

Above the Cap Rock lies a level to slightly sloping area referred to as the High Plains, ranging in elevation from about 3,000 feet to 4,000 feet. This area is traversed by the Canadian River, which by a deeply incised canyon, separates the area into two parts known as the Panhandle or North Plains, and the South Plains.

Topographic changes in the Trans-Pecos province vary from about 900 feet at Del Rio to 8,751 feet at the top of Guadalupe Peak, the highest point in Texas. Other principal mountains and their elevations are: Mount Livermore (Old Baldy) 8,382 feet; El Capitan 8,078 feet; Mount Emory 7,835 feet; Sawtooth Mountain 7,748 feet; Lost Mine Peak 7,550 feet; Blue Mountain 7,330 feet; and Mount Locke 6,791 feet. The area east of the Davis Mountains to the Pecos River is a broken to rolling plain with elevations ranging from 2,000 feet to 4,000 feet.

Topographic differences have provided innumerable watercourses for the drainage of excess rainfall. As these small watercourses reach points of equal elevation with other channels they unite to form a common stream.

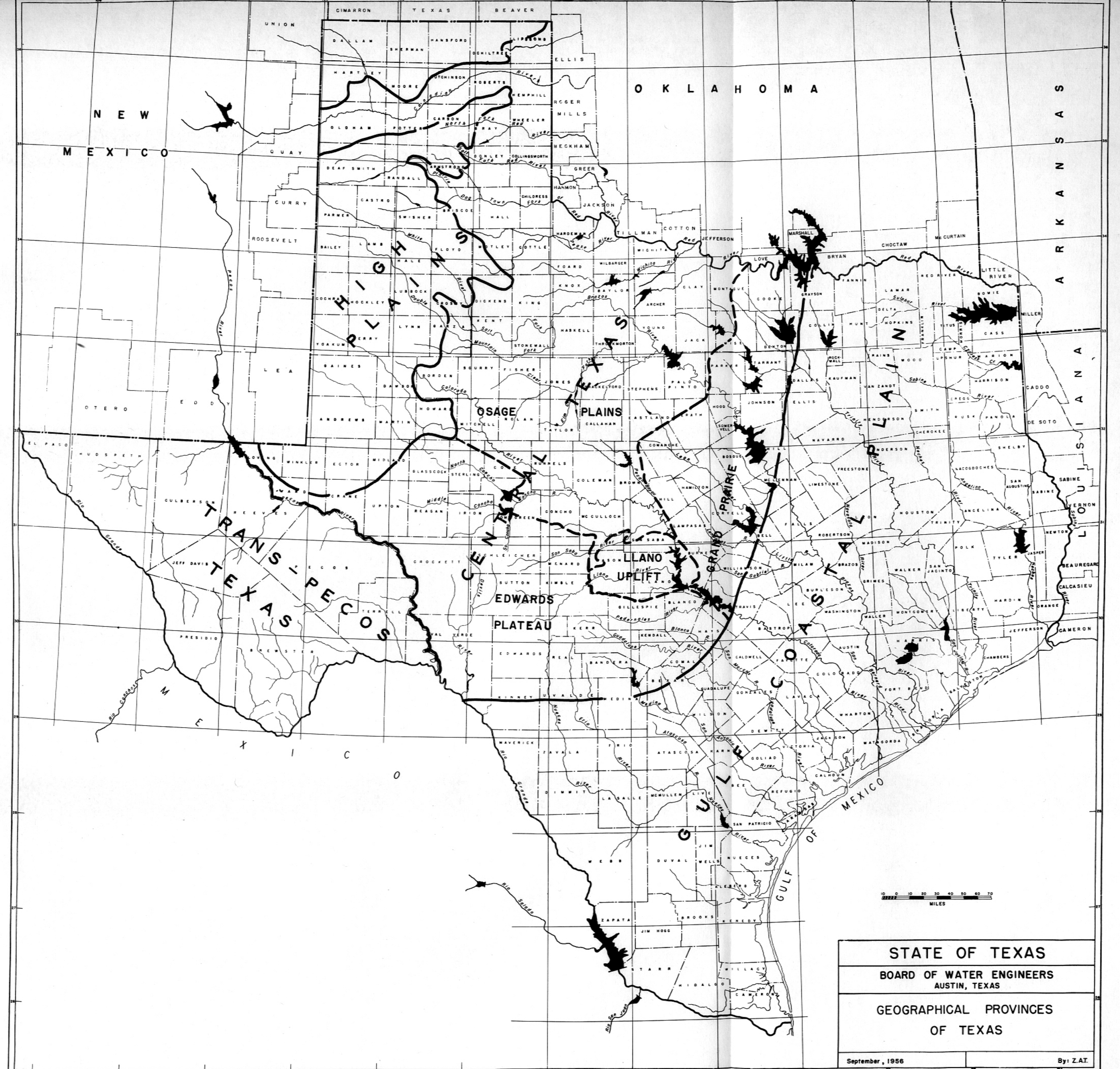

STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
GEOGRAPHICAL PROVINCES OF TEXAS
September, 1956
By: Z.A.T.
HIGH PLAINS
OSAGE PLAINS
CENTRAL TEXAS
LLANO UPLIFT
EDWARDS PLATEAU
TRANS-PECOS TEXAS
GRAND PRAIRIE
GULF COASTAL PLAIN
OKLAHOMA
NEW MEXICO
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO

FIGURE - I

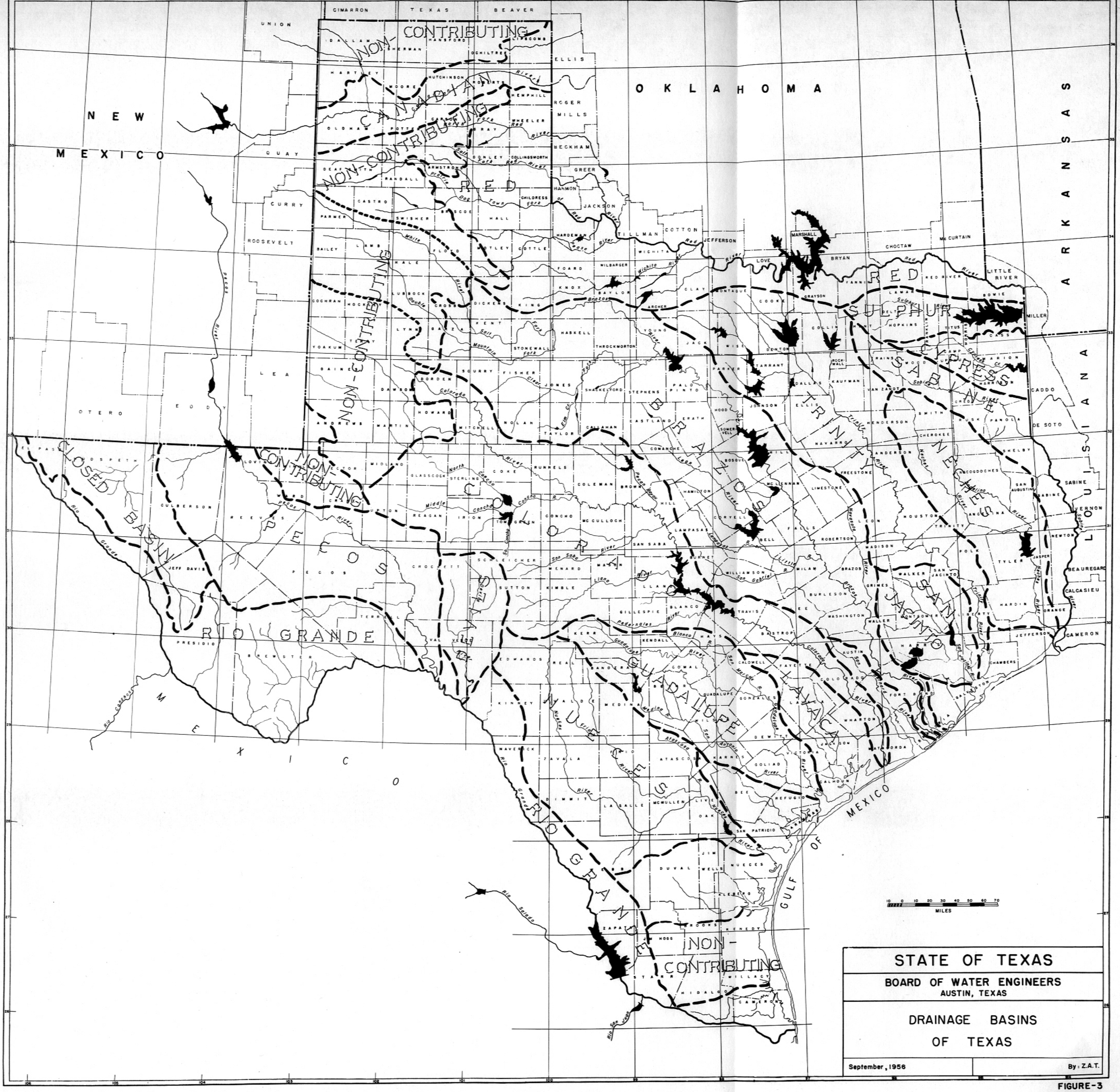

STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
DRAINAGE BASINS
OF TEXAS
September, 1956
By: Z.A.T.
NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO
NON-CONTRIBUTING
CANADIAN
RED
SULPHUR
CYPRESS
SABINE
NECHES
TRINITY
SAN JACINTO
BRAZOS
COLORADO
LAVACA
GUADALUPE
SAN ANTONIO
NUECES
RIO GRANDE
PECOS
CLOSED BASIN
MILES

FIGURE-3

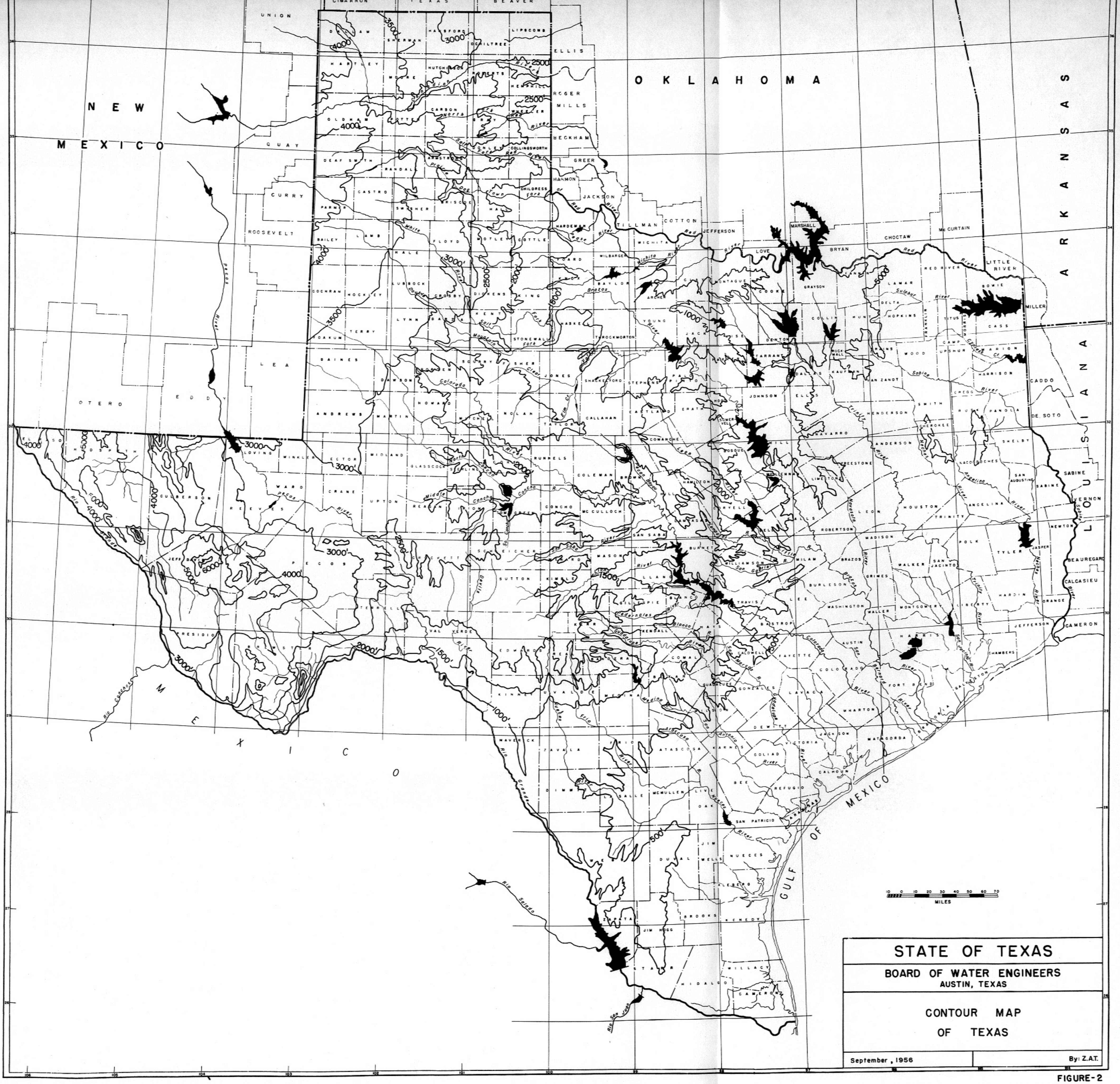

NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO
MILES
STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
CONTOUR MAP
OF TEXAS
September, 1956
By: Z.A.T.

FIGURE-2

The collection of many channels into common streams has provided Texas with its present system of drainage basins, practically all of which slope in a southeasterly direction. As used herein a river watershed, or drainage basin, is the entire area drained by a stream or system of connecting streams such that all run-off originating within the area is discharged through a single outlet. In the instances of certain streams flowing into the Gulf of Mexico multiple channels through the alluvial delta deposits would constitute a single outlet.

Areas containing closed drainage, or for which there is no surface outlet, are found in some basins, such as the Diablo Bolson in the Trans-Pecos province. The largest and most significant of these non-contributing areas is the High Plains, which furnishes little or no run-off to the drainage basins below. This is an area in which the stream flow collects in sinks or lakes and does not have a surface outlet to the other streams within the surrounding basin. Such areas are usually designated as non-contributing to the basin run-off although ground water connections may exist.

Drainage basins may be divided into groups by geographic provinces, the points of discharge from the State, or into political subdivisions.

Texas streams can be defined as being within two broad categories, i.e., those that drain into the Gulf of Mexico, or those that drain into the Mississippi River. The latter includes the Canadian River, Red River, Sulphur River, and Cypress Creek. The Sulphur River and Cypress Creek are part of the Red River system, but have their confluence beyond the State boundary. All other Texas streams (excluding closed basins) empty into the Gulf of Mexico.

The principal stream basins, their drainage areas, and the portions of each in the four geographic provinces are contained in Table 1. The approximate outlines of these basins are shown on Figure 3. Many relatively small drainage basins are situated along the Gulf Coast. Rather than distinguish between these many areas, they have been combined under a single notation at the end of Table 1 as Miscellaneous Coastal Drainage.

Three streams form part of the State's boundary, i.e. the Red and Sabine rivers and the Rio Grande. While the total drainage area of these streams comprise areas in adjacent states and Mexico the drainage areas given in Table 1 are the Texas portions only. According to this definition the largest basin area-wise in the State is the Brazos River. With the Pecos and Devils River basins combined with the Rio Grande, that stream would be second in size.

The areas shown in Column 1, Table 1, include the total land area of Texas, which is indicated by the Texas Almanac to be 263,644 square miles. This includes all or part of 17 separate drainage areas, plus the strip of poorly defined coastal drainage extending along the Coast from the Sabine River to the Rio Grande, as well as certain areas that are, for the purposes of this report, non-contributing. All but 3 of the 19 separate units, as designated in the above table, are represented on the Coastal Plains, the three exceptions being: Canadian, Pecos, and Devils Rivers.

TABLE 1
DRAINAGE BASIN AREAS OF TEXAS

Units: Square Miles

Basin	Total	Gulf Coastal Plain	Central Texas	Trans Pecos	High Plains
1. Red River	27,035	3,640	18,350	-	5,045[1]
2. Sulphur River	3,466	3,466	-	-	-
3. Cypress Creek	2,930	2,930	-	-	-
4. Canadian River	12,933	-	8,393	-	4,540[2]
5. Sabine River	7,360	7,360	-	-	-
6. Neches River	9,175	9,175	-	-	-
7. Trinity River	17,753	11,633	6,120	-	-
8. San Jacinto River	2,880	2,880	-	-	-
9. Brazos River	41,710	9,116	26,294	-	6,300[3]
10. Colorado River	37,780	2,990	26,490	-	8,300[4]
11. Lavaca River	4,213	4,213	-	-	-
12. Guadalupe River	10,218	8,221	1,997	-	-
13. Mission River	1,386	1,386	-	-	-
14. Nueces River	16,910	13,847	3,063	-	-
15. Devils River	4,185	-	4,185	-	-
16. Pecos River	15,753	-	-	15,753	-
17. Rio Grande	20,223	6,218	-	14,005	-
18. Misc. Coastal Streams	11,990	11,990	-	-	-
19. Non-Contributing Ecl. of 1, 2, 3, & 4	15,744	4,700	-	8,284	2,760
Total Land Area	263,644	103,765	94,892	38,042	26,945
Percent	100.0	39.4	36.0	14.4	10.2

Only eight, or less than half of the separate drainage basins, are represented in the Central Texas Province. In the Trans-Pecos Province only the Rio Grande and its tributaries are represented, while four of the larger drainage basins extend onto or across the High Plains.

The respective areas are made up percentage-wise as indicated at the bottom of Table 1 to be:

	Area sq. miles	% of Total Land Area
Gulf Coastal Province	103,765	39.4
Central Texas Province	94,892	36.0
Trans-Pecos Texas	38,042	14.4
High Plains	26,945	10.2
Total	263,644	100.0

The area in Texas included within the Gulf Coastal Plain comprises nearly 40 percent of the total land area of the State. This is a land of gently rolling plains, most of which is between zero and 500 feet in elevation; the only area of the Coastal Plain above 500 feet being in the west extremity of the Coastal Plain near Del Rio.

The Central Texas Province, which immediately adjoins the Coastal Plain, and extends westward to the Pecos River or the High Plains, makes up another 36 percent of the total land area of the State.

These two provinces together take up more than three-quarters (75.4%) of the entire State. This leaves less than one-quarter of the State to be made up by the sum of the two remaining provinces.

Another analysis of the drainage areas shown in Table 1 makes the separation as to streams that empty into the Lower Mississippi River as distinguished from those which enter the Gulf of Mexico directly. The first four items in the Table, which are as follows: Red River, Sulphur River, Cypress Creek, and Canadian River, all empty into the Mississippi River, with their respective areas in Texas being shown below.

	Drainage Area Sq. Miles	% of Total Land Area
Red River	27,035	10.3
Sulphur River	3,466	1.3
Cypress Creek	2,930	1.1
Canadian River	12,933	4.9
Total	46,364	17.6

This total area of 46,364 square miles, being 17.6 percent of the total land area, leaves that remaining area which contributes directly to the Gulf, or is non-contributing, as 217,280 square miles or 82.4 percent of the area of the State.

Out of the total land area there is a non-contributing area (which furnishes no run-off for use outside its watershed boundaries) made up as follows:

	Sq. Miles	% of Total Land Area
On the Gulf Coastal Plain (between Nueces River and Rio Grande)	4,700	1.8
Trans-Pecos Texas	8,284	3.1
All of the High Plains	26,945	10.2
Total	39,929	15.1

In other words, the remaining area of 223,715 square miles, or about 85 percent of the area of the State of Texas, contributes all of the run-off which escapes from the State. However, all of this area does not contribute run-off to the same degree, since the run-off increases from zero along the western boundary of this area, to its highest rate in Texas along the eastern boundary.

Since at least 15 percent of the State contributes no run-off, it is hardly appropriate to say that Texas wastes so much water into the Gulf each year. Only a part of the area of the state contributes. It is eminently worthwhile to locate this area that contributes the run-off and note the distribution of run-off with respect thereto. This distribution will be more fully discussed under the subject of run-off.

AVERAGE ANNUAL RAINFALL IN TEXAS

The map showing average annual rainfall in Texas was prepared by the Texas Board of Water Engineers, and is the same as shown following page 22 in the Twenty-First Report of the Board, covering the biennium September 1, 1952 to August 31, 1954. It is included herein as Figure 4.

This map is based on many records of rainfall, wherein only those stations having five years of record, or more, were used. After these stations were plotted lines of equal rainfall were interpolated at 5-inch intervals. Since no set period of time is covered by the stations records, there is probably some minor distortion caused by using certain 5-year records along with others which may have more than 50 years of record. However, for the purpose for which this map is used, such distortion would be insignificant.

As of December 31, 1955 rainfall measuring stations had been operated at various times at 1292 points in Texas.[5] Of this total, data from 634 stations were reported in the U. S. Weather Bureau 1955 Annual Climatological Summary.

The most important feature of this rainfall map is that precipitation is not evenly distributed over the State. Quite the contrary is true. Whereas average annual rainfall along the Louisiana border is indicated to be in excess of 55 inches, the average annual rainfall is shown to be less than 10 inches in the western extremity of Texas. Of secondary importance is the fact that the lines of equal rainfall run generally north and south. The decrease from east to west is greatly pronounced, although not necessarily following a uniform rate of diminution in this respect. This is well illustrated by the following examples:

Average Annual Rainfall in Inches

East to West		North to South	
Bon Weir	56.51"	Wichita Falls	27.39"
El Paso	8.63"	Brownsville	27.71"

Two charts have been prepared, and are included as Figures 5 and 6, which show the variation in average annual rainfall for shorter periods of time, and covering only a portion of the State. The average annual rainfall for the four-year period 1944-47 by 2-inch intervals for the area drained by the Trinity, Brazos and Colorado Rivers, is shown on Figure 5. These four years were characterized by above normal rainfall, the range extending from 12.17 inches near the Texas-New Mexico border to 68.50 inches near the mouth of the Trinity River.

Figure 6 shows the average annual rainfall over the same area for the period 1950-53, which reflects the lower rainfall incident to the current drought. During this period the range in average rainfall from west to east was 8.01 inches in Southeastern New Mexico to 53.63 inches

5. Substation History, Texas, U. S. Weather Bureau, 1956

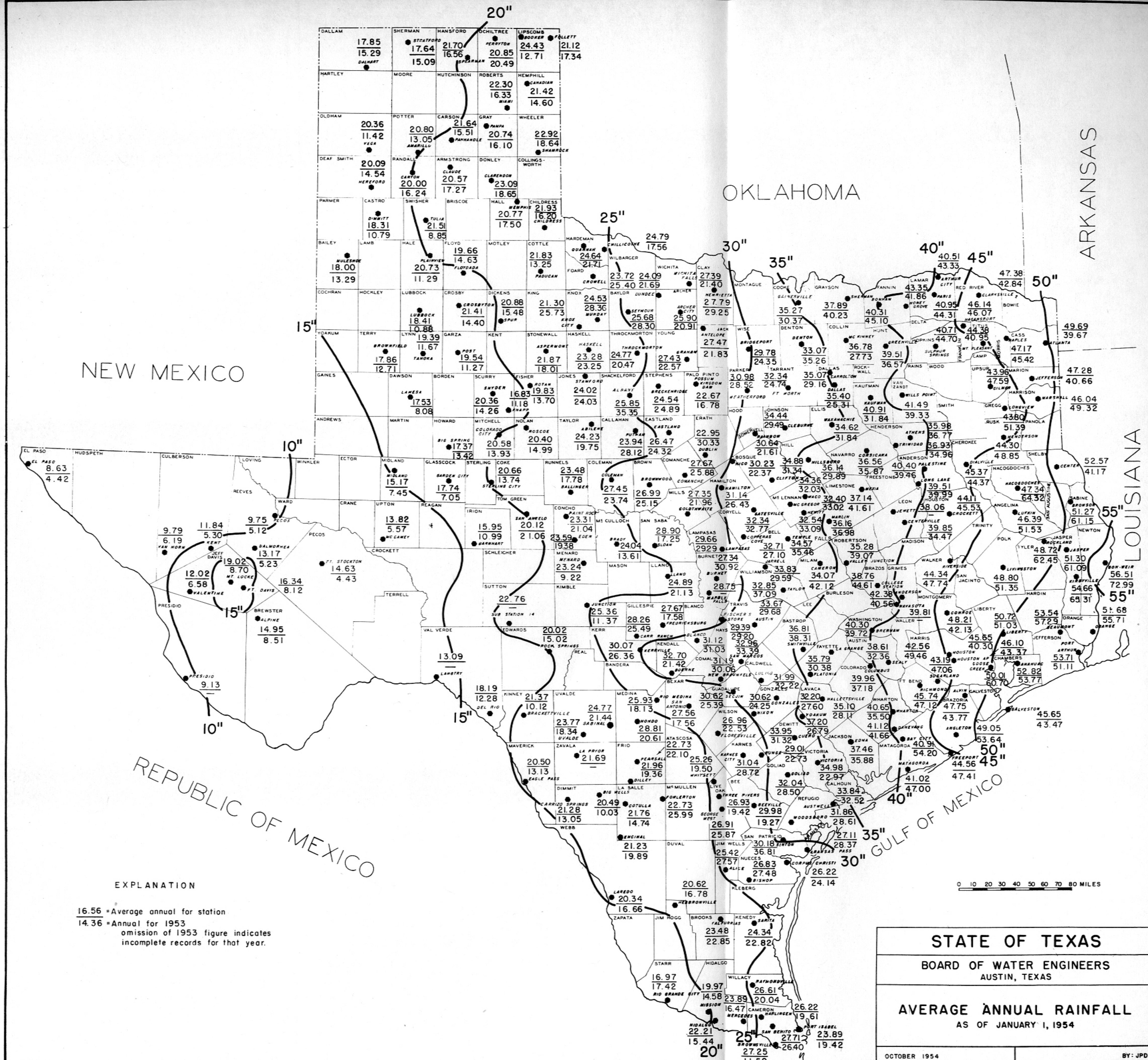
near the mouth of the Trinity River. A comparison of a cross-section of stations along a line from northwest to southeast shows the relative rainfall in the respective periods to be as follows:

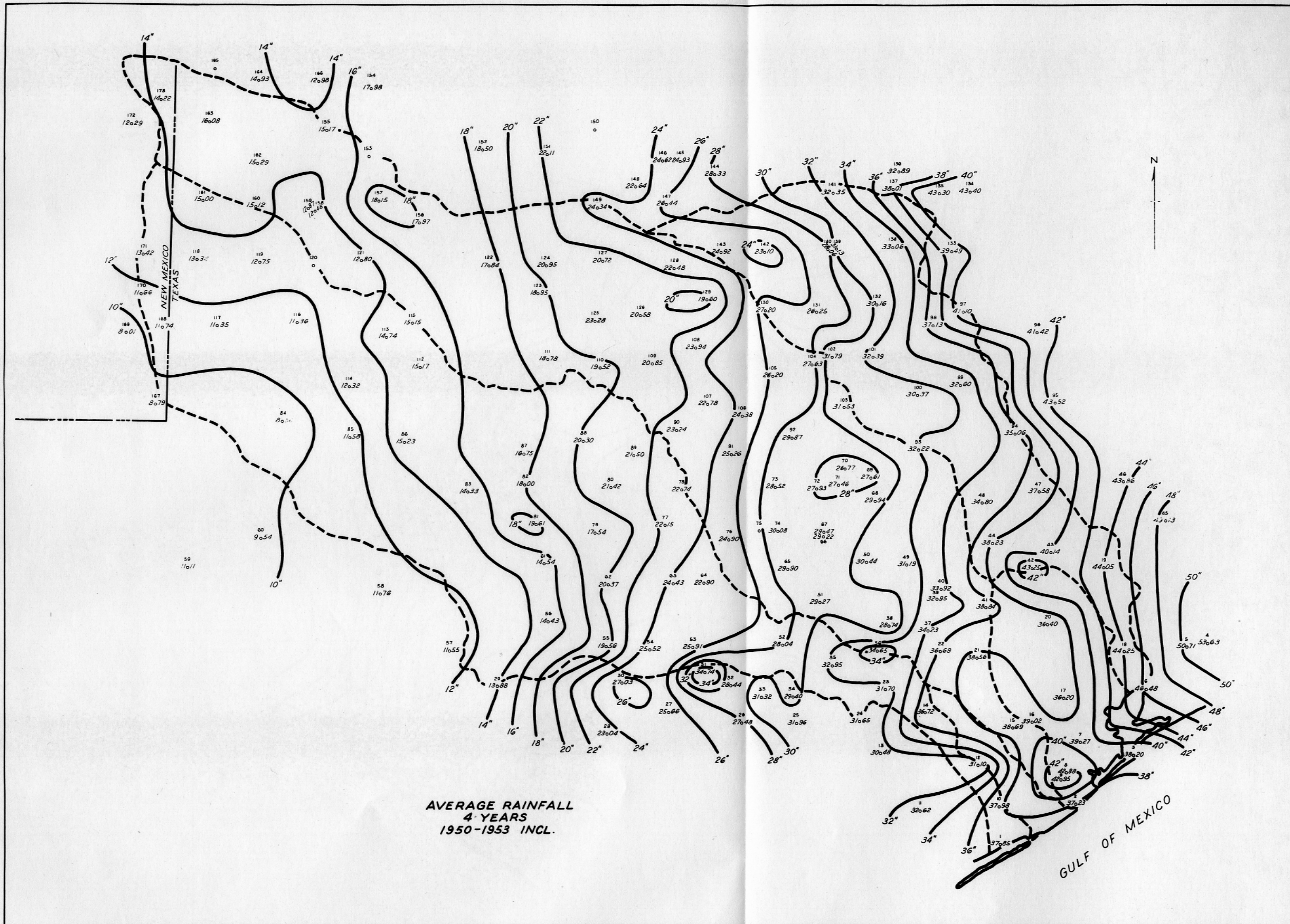
Stations by Number	Station Name	Average Annual Rainfall--Inches 1944-47	1950-53
161	Morton	12.60	15.00
115	Snyder	21.61	15.05
88	Coleman	27.99	20.30
76	Lampasas	34.00	24.90
38	Dime Box	40.54	28.74
16	Sugarland	55.22	39.02
Average		31.99	23.83

There is a difference in the average rainfall of more than 8 inches per year between the two 4-year periods. Based on the selected rainfall stations above, this is not necessarily a true average, but it is an index to the difference in rainfall. While there is an average difference of only about 8 inches indicated by the index figures, it may be noted that in the eastern part of the area, the difference in rainfall between the two periods is greater than 16 inches.

It is also significant that rainfall characteristics may vary quite widely in different parts of the State within the same 12-months period. For instance, the rainfall in 1953 at El Paso was 4.42 inches, which compares with an average annual rainfall of 8.63 inches at the same point. Bon Weir, on the eastern border of the state, shows a total of 72.99 inches in 1953 as compared to a long-time average of 56.51 inches. In one case the 1953 rainfall was 51 percent of normal, while in the other it was 129 percent. Both rainfall stations are in Texas, and the period cited was identical for each.

The fact that climatic conditions can be so radically different on opposite sides of the State at the same time, discloses some of the errors that naturally follow when run-off and rainfall averages over the State as as a whole are used.


STATE OF TEXAS
BOARD OF WATER ENGINEERS
AUSTIN, TEXAS
AVERAGE ANNUAL RAINFALL
AS OF JANUARY 1, 1954
OCTOBER 1954
BY: JPD
EXPLANATION
16.56 = Average annual for station
14.36 = Annual for 1953
omission of 1953 figure indicates incomplete records for that year.
0 10 20 30 40 50 60 70 80 MILES
NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
REPUBLIC OF MEXICO
GULF OF MEXICO
10"
15"
20"
25"
30"
35"
40"
45"
50"
55"
Figure 4



AVERAGE RAINFALL
4 YEARS
1950-1953 INCL.

Figure 6

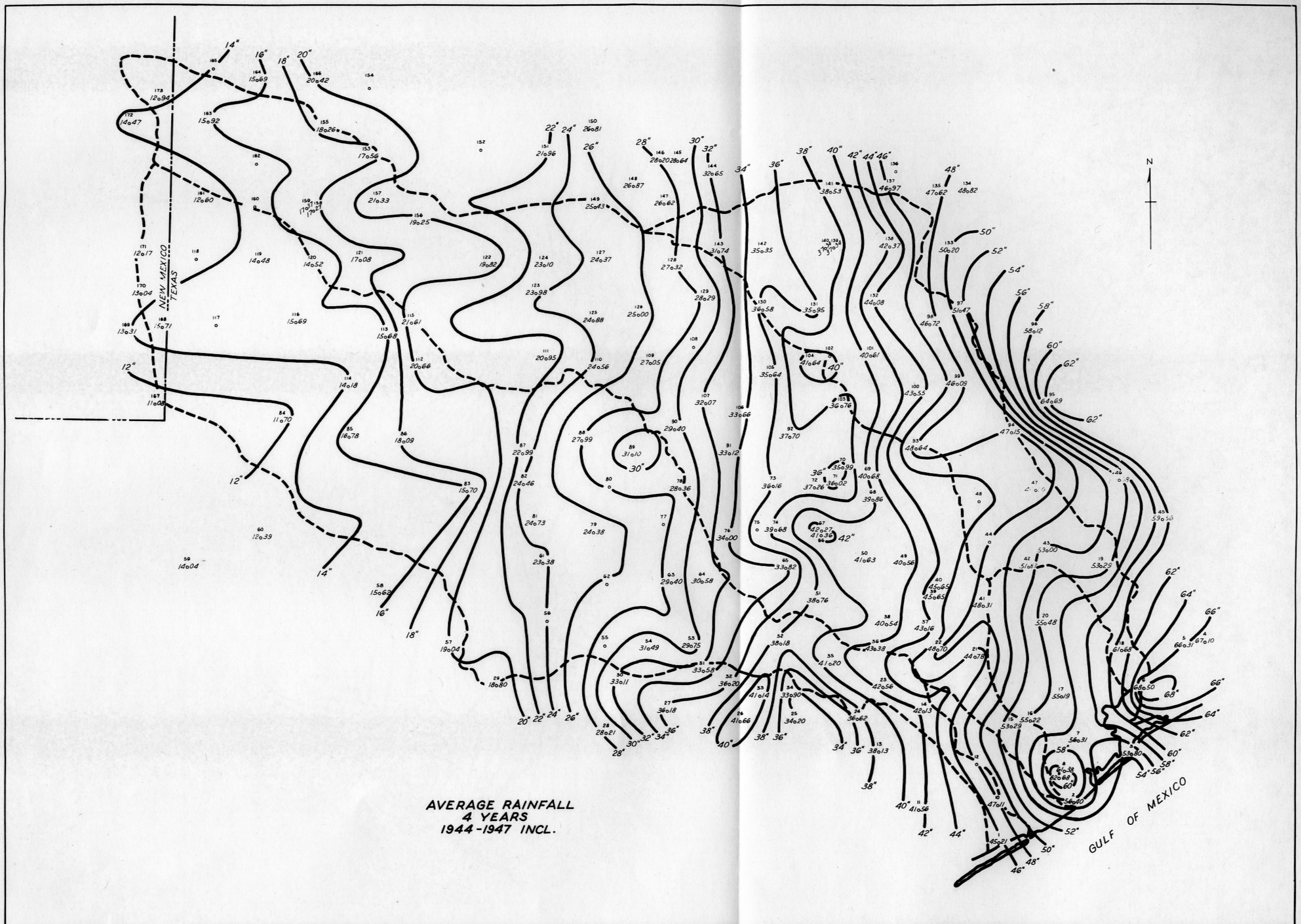

AVERAGE RAINFALL
4 YEARS
1944-1947 INCL.
NEW MEXICO
TEXAS
GULF OF MEXICO
N

Figure 5

WATERSHED USES IN TEXAS.

The gross water supply of the State is composed of the inflow from adjoining states on international and interstate streams, plus the rainfall that occurs in Texas. Of the two sources the latter is by far the larger. While rainfall over the State provides the stream flows considered in the succeeding portions of this report, the two items are not synonymous. Rainfall over a given area provides, in general, the gross water supply while the run-off or stream flow from this same area is the residual or net water supply.

The difference between rainfall and run-off consists of the uses of rainfall for various purposes on the watershed. While this difference is sometimes referred to in technical literature as "evapo-transpiration losses" it will be referred to herein as "watershed uses." The word "losses" might be misleading for it implies a lack of use of the rainfall which is not the case. Some of the rainfall is intercepted by vegetation and evaporated back into the atmosphere without even reaching the ground. A part of it infiltrates into the soil to reach the water table. Any of this ground water that subsequently enters a stream is reflected in the measured run-off from the area. A much larger part is held by capillarity within the root zone of the vegetation that exists, where it is either used by plants, or is drawn back into the atmosphere by evaporation from the soil. Rainfall in excess of the infiltration capacity in one area moves down slope toward defined water-courses as run-off. In this movement it may cross areas where the rainfall has not exceeded the infiltration capacity and this overland flow would be reduced accordingly. Some of the flow entering water-courses empties into natural closed basins, to be largely dissipated by evaporation. Other parts of this flow reaches man-made basins such as stock tanks, ponds and reservoirs, where a further portion is evaporated. A part of the stream flow is diverted by man to supply domestic and municipal water, to irrigate farms, or for industrial purposes. While these several watershed uses may vary with different areas they are nevertheless reflected in the run-off records of these areas.

As these uses by man have been continuously increasing, the result has been to deplete the water supply. It is expected that such uses will continue to increase in the future, to the extent that the depletions of stream flow will be always larger, leaving the future stream flow as only a fraction of that run-off which has been experienced in the past.

A significant feature incident to the uses of water by man is that such uses are not usually paralleled by the water supply. Most uses, except for industrial purposes, vary with the seasons, being highest during the summer months, when the water supply under natural conditions is lowest. It is this discrepancy between the supply as provided by nature, and the requirements for domestic, municipal and irrigation uses, that makes it necessary to regulate the stream flow by impoundment before maximum benefits can be obtained. The use requirements vary both with the season of the year, and with climatic fluctuations.

Domestic, municipal and industrial water supplies must be available 100 percent of the time, although there is a seasonal variation. Domestic and municipal requirements during the summer months may be three to four times as great as the winter monthly rates. Industrial demands tend to be much more uniform. Irrigation requirements differ from place to place over the State in relation to rainfall (or the lack of rainfall), to temperature differences, to occurrence of frost, and to the types of crops produced. In general, irrigation is practiced from early spring to early fall. Water requirements for the generation of hydro-electric energy follow some seasonal variations, although there is a tendency toward a more uniform distribution throughout the year. Wide fluctuations in the daily demands for these several uses are caused by rainfall and sudden temperature changes.

When adequate storage capacity is provided, a portion of the erratic stream flow, which is surplus during floods, can be captured and made available for later use. Two notable examples of the capture of excessive flood flows for subsequent use may be found in reference to the maximum rates of flood discharge that have been observed in Texas.

The flood of September 1952 on the Colorado River in Central Texas entered Lake Travis above the City of Austin at rates in excess of 800,000 c.f.s. All of such inflow was captured in Lake Travis, however, where it could be later released for beneficial use. A similar instance occurred in July 1954, on the Pecos and Devils Rivers, which emptied into the Rio Grande near Del Rio at rates in excess of 1,000,000 c.f.s. As this extreme flood, breaking all previous records on the Rio Grande, passed downstream it was all captured in Falcon Reservoir to be subsequently released for irrigation and municipal requirements.

In each of the above examples, the flood followed a period of low flow and it was possible to store the entire flood volume in storage space allocated to conservation, without having to make use of the flood control capacity that was available. Unfortunately, all floods do no occur after long periods of drawdown, and all reservoirs do not have adequate conservation capacity to be able similarly to convert 100 percent of the flood water to some beneficial purpose. On the other hand, as more conservation storage capacity is created on all of the streams, a higher proportion of the water that now runs off can be made available to serve some useful purpose before it escapes.

It is not to be presumed by the above discussion that all of the water that leaves the State, either through the Canadian or Red River Basins or directly into the Gulf, has served no useful purpose. On the contrary, power plants in operation on the Brazos, Colorado and Guadalupe rivers have made use of most of the water passing these plants, flood flows generally being excepted. Similarly, a large part of the low flow of the Trinity River is comprised of the sewage effluent from Fort Worth and Dallas. Hence, a beneficial use has already been made of that water.

Under existing conditions and in accordance with present laws, there are certain waters now being wasted from most of the Texas streams. This situation might be brought about under the following circumstances, for example:

> A permit has been granted for the irrigation of a certain area--with the limitation and diversions being an annual use of 8,000 acre-feet, and not to exceed 80 c.f.s. Such is a typical appropriation.

While the appropriation does not guarantee the water supply, under such a right the appropriator is permitted to take up to 80 c.f.s. on any day during the year whenever he so disires, so long as his total does not exceed 8,000 acre-feet during the calendar year. Normally the irrigation season might extend over a period of six months. Actually, there is committed under such an appropriation nearly 60,000 acre-feet per year out of the stream flow of that particular river, because the appropriator can choose the days on which he wants to irrigate. With the law as it now stands, there now is not subject to appropriations the difference between the 8,000 acre-feet actually granted and the 60,000 acre-feet tied up by the permit. Some modification of the law to permit water uses over a period of less than the full year would no doubt be helpful in such a case.

EVAPORATION IN TEXAS *

Evaporation is the climatic process by which moisture is picked up from any source and transported to distant spots by the circulation of the air. The major source of evaporation is the ocean surfaces of the earth, with the free water surfaces of the lakes and ponds contributing at about the same rate. In periods of excessive rainfall, all climatic factors combine to minimize the effect of evaporation. But in dry periods, when the water supply is already reduced, the combination of factors is such that the effect of evaporation becomes a rather significant item in any water supply in Texas.

Due to the great variance in the climatic factors of which evaporation is a function - both with respect to time and place, there is a wide variability in the losses that will result from evaporation.

This matter has been studied extensively in recent years, and many new evaporation stations have been installed in Texas. Three types of pans are currently used which may be identified by name and size as follows:

Name	Size (Inches)	
Young (Screened)	24 diameter - 36 deep	Sunken
Bureau of Plant Industry	72 diameter - 24 deep	Sunken
Weather Bureau	48 diameter - 10 deep	On Low Wood Platform

Efforts have been made to standardize the techniques for measurement, exposure, and protection of the equipment, although the results are not yet perfect in this respect. This has necessitated certain adjustments of data, which have been made after consultation with the staff engineers of the Board of Water Engineers.

Data for the Texas evaporation stations used were obtained in most cases from the records of the Board of Water Engineers. Data for stations near the border of Texas in the states of Arkansas, Louisiana, Oklahoma, and New Mexico were taken from the U. S. Weather Bureau publications. Records along the Rio Grande in the United States and Mexico were obtained from the reports of the International Boundary and Water Commission.

Evaporation measured from the different types of pans varies with the actual lake surface evaporation -- presumably because of the difference in the volume of water involved. Annual coefficients to convert each set of records to reservoir surface equivalents have been recommended by the Board of Water Engineers. A seasonal variation in the coefficients has been recognized, and monthly coefficients for each type of pan have been derived -- within the limits of these annual coefficients. The lake surface evaporation was then corrected for the local rainfall. The results thus obtained indicate the net evaporation loss.

The map contained as Figure 7 was prepared by first locating the average station records for the 5-year period 1951-1955, and then interpolating

* Previously prepared for the Texas Electric Service Company and used herein with their consent.

the lines of equal evaporation (in terms of the net annual loss). It is significant that during this period rainfall was generally low, temperatures were high, and evaporation losses were greater than usual. However, it is the high evaporation losses in these critical years that have to be taken into account in reservoir design and water supply problems. There is an extreme range in the annual net losses that varies from near zero along the eastern border of the State to more than 120 inches in the Big Bend Country. The general trend of the lines of equal evaporation loss is noticeably north and south.

Evaporation losses vary not only from one part of the State to another, but also from season to season. Records that have been examined for many evaporation stations over a long period of time show that the losses during the six warmer months of the year may constitute as high as 80 percent of the annual losses, leaving 20 percent for the remaining six-month period. In the more westerly part of the state, where evaporation losses are relatively high, this may mean that as much as 60 inches of water may be lost from a reservoir surface within a 6-month period. Translated into terms of reservoir loss it can thus be seen that any reservoir in the western area less than 5 feet in depth can be emptied by evaporation alone within a 6-month period. It is only where water can be stored more efficiently than this that any carry-over storage can be accumulated to serve some useful purpose at a later date.

RUN-OFF IN TEXAS

General

One of the most hackneyed phrases persistent in Texas today has to do with the run-off from Texas that enters the Gulf of Mexico each year. In this connection the State as a whole has been used as a unit. Run-off does not emanate from the state as a whole; there are only certain portions of the state which contribute to the Gulf. Other sections of the state furnish no run-off outside of their immediate areas, and contribute nothing to the Gulf of Mexico. It is the purpose of this study to outline the areas that do furnish run-off and to show the relative amounts from each such source.

Many studies of surface run-off in Texas have been prepared in the past. Each Water Supply Paper of the U. S. Geological Survey - Part VIII, Surface Water Supply of Western Gulf of Mexico Basins, is in fact an inventory of the surface run-off for that particular 12-month period, extending in this case from October 1 of one year to September 30th of the following year. The Water Supply Paper of Part VII, Surface Water Supply of Lower Mississippi River Basins, include additional water that flows out of Texas.

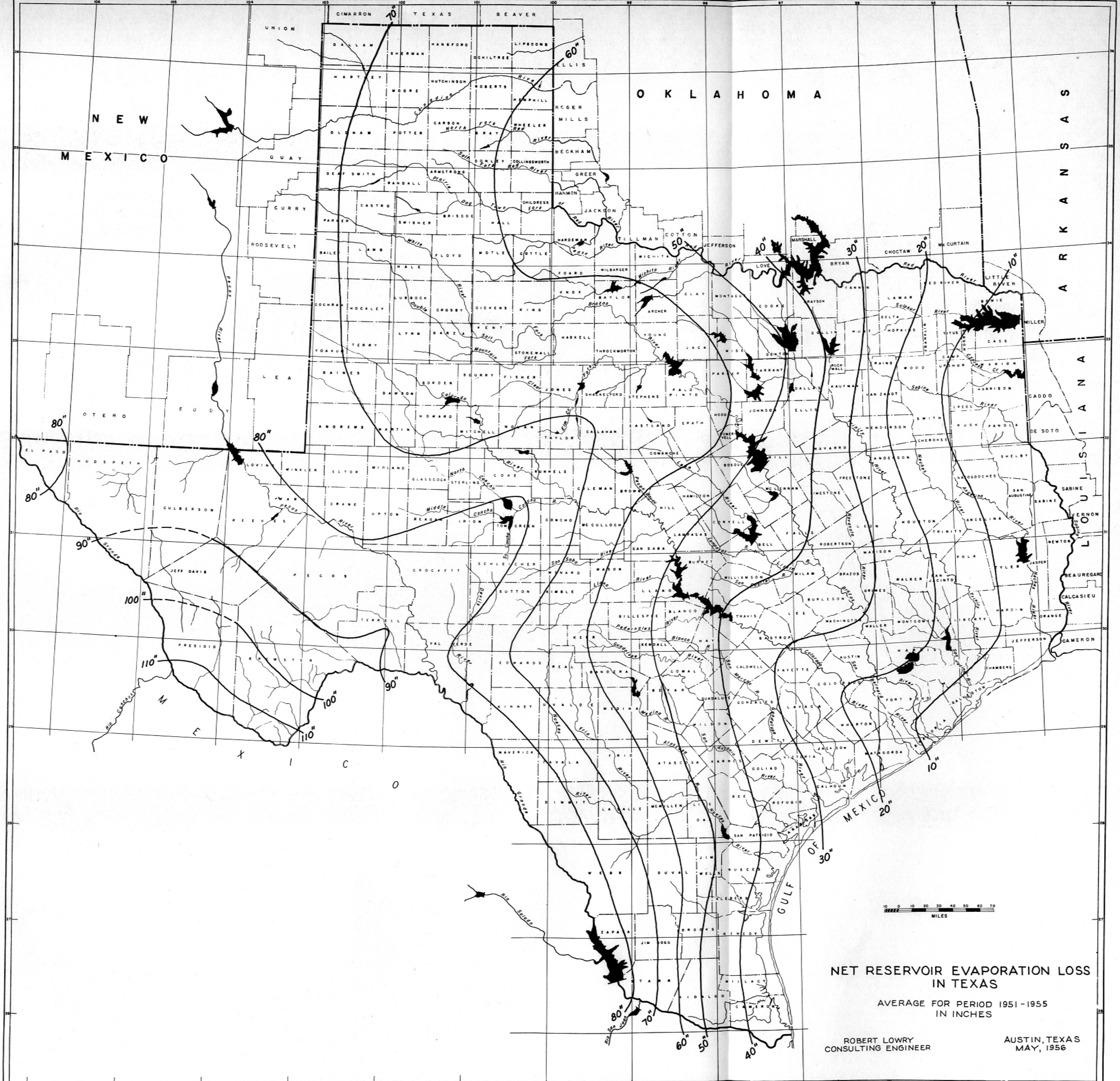
Still further information on flows in Texas rivers may be found in the Water Bulletins of the International Boundary and Water Commission, with particular reference to the Rio Grande.

Run-off of the many streams and springs of Texas is measured by the U. S. Geological Survey and International Boundary and Water Commission in cooperation with relevant State, local, and Federal agencies. As of October 1, 1955, 320 gaging stations were in operation by the agencies above mentioned. While many of these stations have been established during recent years, the data so obtained are becoming increasingly important. In addition, past records at 120 stations, not now in operation, are also available.

Stream discharge records reflect the historic conditions of water use on the drainage areas above the gaging stations. In many instances progressive changes have been taking place on the watersheds. Thus the use of historic run-off data over a long period of time would require a correction for these progressive changes. By making these adjustments the present condition water supply can be obtained. Therefore the water supply of the State under "present conditions" is the historic run-off corrected for the uses that have taken place.

In the planning of new projects for the use of surface waters an additional correction must be applied. Thus the water supply under "present conditions" when modified for new developments represents the basin's water supply under projected future conditions.

The complex nature of the problem, coupled with the paucity of information on past, present and possible future developments and water uses, has precluded the mathematical definition in this report of the present and future water supplies of the State. However, in recognition of this situation the use of stream flow records herein has been limited to the fifteen calendar-year period, 1940 through 1954. It cannot be over-emphasized



NET RESERVOIR EVAPORATION LOSS IN TEXAS

AVERAGE FOR PERIOD 1951-1955
IN INCHES

ROBERT LOWRY
CONSULTING ENGINEER

AUSTIN, TEXAS
MAY, 1956

Figure 7

that the run-off data contained herein cover "historical" conditions rather than "present" conditions.

For the purposes of this report the following assumed division of water on boundary streams has been made:

Rio Grande (at mouth)	50% to Texas
Sabine River	Entire flow at Logansport plus 50% of inflow below Logansport to Texas
Red River	50% to Texas

Run-Off by Geographic Provinces

The four principal geographic provinces of Texas have previously been defined. In a similar manner the major drainage basins of the State have been described. While these areas have contrasting physiographic differences there are also certain climatic variations. These climatic differences influence to a considerable extent the run-off from the areas.

During the study period, 1940 through 1954, the average historic run-off that could be credited to Texas would be (after modification for international and interstate treaties) 44,150,000 acre-feet. Annual values have been derived for each geographic province as shown in Table 2. These data are depicted graphically on Figure 8.

While an average figure of 44,150,000 acre-feet for the annual run-off is indicated for this 15-year period, such an average means nothing. There have been greatly divergent climatic conditions that have prevailed within even this short period. Note the difference in rainfall as shown for the four-year period 1944-47 (Figure 5) as compared with the corresponding rainfall for the later four-year period 1950-53 (Figure 6). The run-off has also varied quite widely. See Figures 13, 14, and 15, which show the run-off of the Trinity, Brazos and Colorado river basins for the 30-year period, 1924 through 1953.

Consider the run-off for these same two periods as derived from the Gulf Coastal Plain and the Central Texas Province.

Year	Annual Run-Off (1000 AF) Coastal Plain	Central Texas	Comments
1944	46,993.0	9,119.0	
1945	58,054.0	14,799.0	Rainfall above normal
1946	64,439.0	10,648.0	
1947	30,178.0	7,942.0	
Average	49,916.0	10,627.0	

Year	Annual Run-Off (1000 AF) Coastal Plain	Central Texas	Comments
1950	40,975.0	8,102.0	
1951	11,810.0	4,825.0	Rainfall below normal
1952	18,806.0	3,072.0	
1953	31,583.0	3,624.0	
Average	25,799.0	4,906.0	

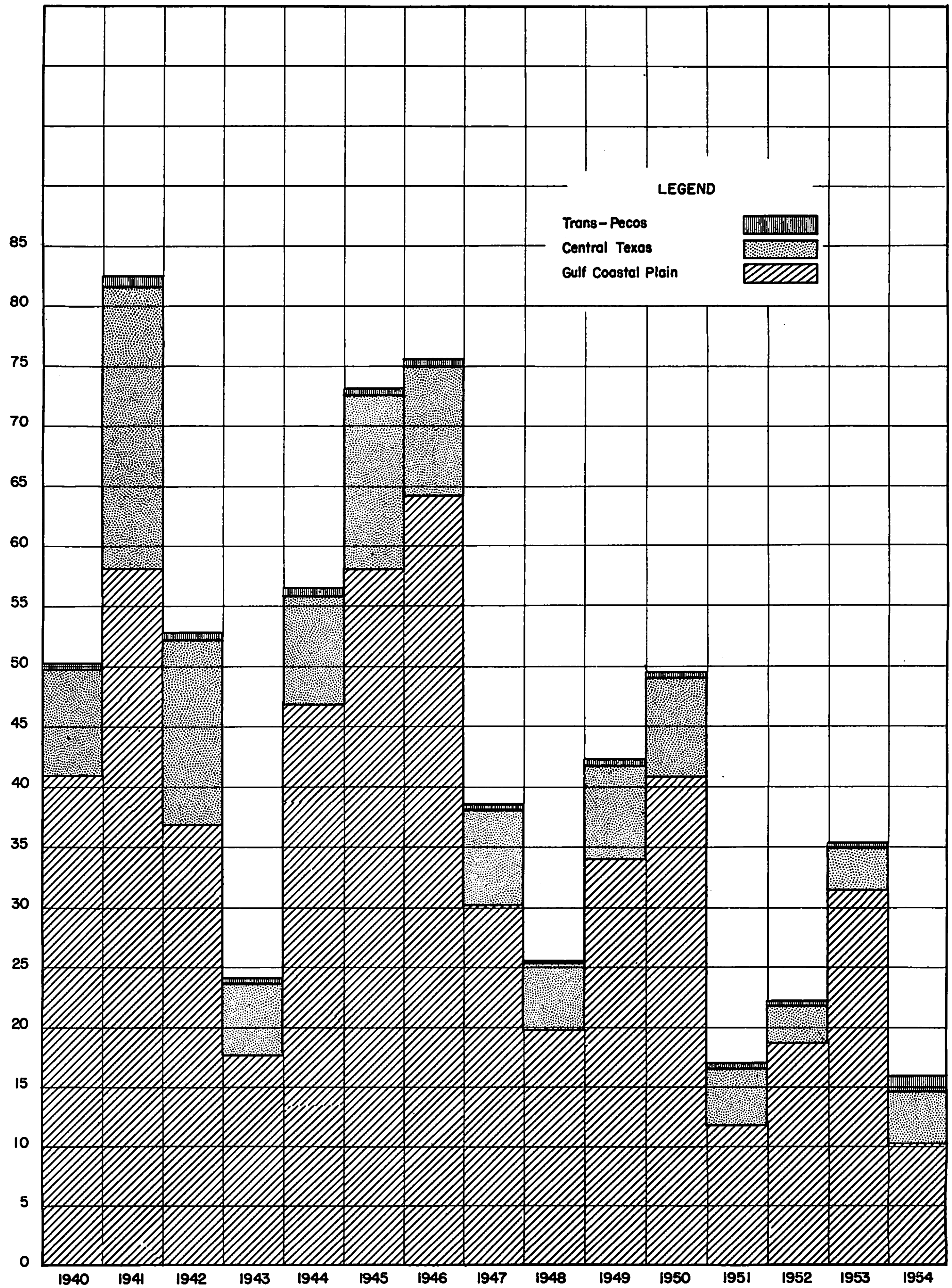


FIGURE-8.

RUN-OFF BY GEOGRAPHIC PROVINCES OF TEXAS

TABLE 2
SUMMARY ANNUAL HISTORIC RUN-OFF BY
GEOGRAPHIC PROVINCES

Units: Acre-Feet

Year	Gulf Coastal Plain	Central Texas	Trans-Pecos Texas	High Plains	Total
1940	41,018,000	8,763,000	482,000	0	50,263,000
1941	58,122,000	23,571,000	843,000	0	82,536,000
1942	36,973,000	15,321,000	538,000	0	52,832,000
1943	17,795,000	5,945,000	442,000	0	24,182,000
1944	46,993,000	9,119,000	422,000	0	56,534,000
1945	58,054,000	14,799,000	461,000	0	73,314,000
1946	64,439,000	10,648,000	659,000	0	75,746,000
1947	30,178,000	7,942,000	517,000	0	38,637,000
1948	19,961,000	5,487,000	72,000	0	25,520,000
1949	34,009,000	7,869,000	552,000	0	42,430,000
1950	40,975,000	8,102,000	515,000	0	49,592,000
1951	11,810,000	4,825,000	382,000	0	17,017,000
1952	18,806,000	3,072,000	374,000	0	22,252,000
1953	31,583,000	3,624,000	197,000	0	35,404,000
1954	10,263,000	4,391,000	1,330,000	0	15,984,000
Average	34,732,000	8,899,000	519,000	0	44,150,000
Percent	78.6	20.2	1.2	0	100.0

In terms of percentage of the 15-year average run-off for each of these provinces, the variation within the respective 4-year periods was as follows:

Run-Off From	Percentage of 15-Year 1944-47	Average 1950-53
Gulf Coast Plain	144%	31%
Central Texas Province	290%	55%

It is noticeable that in terms of the total run-off of the State of Texas, the average for the first seven years of the period, 1940-1946, was 59,344,000 acre-feet, while the average for the last 8 years has only been 30,854,000 acre-feet, indicating that in recent years the run-off was only about half of that which was experienced in the earlier period. During the latter four years of this 8-year period the average run-off was only 22,664,000 acre-feet annually. This is the most significant figure given, because it represents all of the water that is escaping from the state under conditions that have prevailed over this four-year period. Only a fraction of this amount could be economically put to use - possibly about two-thirds, which means there is a possibility of developing from this run-off only about 15,000,000 acre-feet per year, even with some regulation of the stream flow by storage. The only way in which this figure could be significantly increased and the water put to a useful purpose is through the creation of a large amount of storage, sufficient to carry over from the periods of excessive run-off which occurred prior to this 4-year period of low flow. The need for carryover storage is further emphasized by the fact that the total annual flow during two out of these last four years was as low as follows:

1951 - 17,017,000 acre-feet
1954 - 15,984,000 acre-feet

As the current drought is prolonged it further extends the length of time for which the carryover storage would have to be provided. In some parts of the State the carryover period is already into its eighth year. Also, there are certain parts of the state where eight years is already beyond the limit for which carryover storage may be provided, due to evaporation losses alone.

Data in Table 2 indicate that for the period the Gulf Coastal Plain Province provided an average of 78.6 percent of the total run-off, the Central Texas Province 20.2 percent, the Trans-Pecos Texas area 1.2 percent, and the High Plains Province zero percent of the run-off. With the High Plains contributing none of the run-off, and the Trans-Pecos Texas area furnishing only 1.2 percent of the total, it si obvious that the other two geographic provinces, the Gulf Coastal Plain and Central Texas, must be looked to for all of the run-off. Since the run-off and climatic conditions of each province have wide variations each area will be discussed individually.

Gulf Coastal Plain Province

As shown on Figure 1 this province includes the area from the Red River below Denison Dam to the Rio Grande below Del Rio.

The streams in the more easterly portion of this area are remarkably regular in flow, a large part of which is made up of the base flow. This is the natural accretion to the streams in an area where the water table is above stream level. Below the Brazos River and to the west, there is a tendency for the stream flow to become more erratic, as the rainfall decreases, and the ground-water level becomes progressively lower.

Some of the largest water producing streams in the State have drainage basins situated completely within this area, while some of the other longer streams extend through parts of the other geographic provinces.

The principal streams or appropriate portions thereof that lie on the Coastal Plain, their drainage areas, and their run-off by years are listed in Table 3. These are summarized in Table 4, which shows the average distribution of the run-off of the areas within the Gulf Coastal Plain province. In Table 2 of this report it was shown that 78.6 percent of the run-off of the entire State originated in the Gulf Coastal Plain. Of this amount Table 4 shows that about 88-1/2 percent of the total run-off of the Gulf Coastal Plain in Texas originates from the eastern portion thereof, or that area from the Brazos River to the Texas-Louisiana boundary. The drainage area covered by these streams aggregates 54,120 square miles, or 20.6 percent of the land area of Texas, which total 263,644 square miles. It may thus be seen that this relatively small portion of the State furnishes nearly 70 percent of the total run-off of the State. The remainder of the run-off from the Coastal Plain, which originates south and west of the Brazos River, makes up a total of only 11.5 percent of the total run-off from the Coastal Plain. In terms of the total run-off from the state as a whole, this is only about 9.1 percent, yet the area involved equals 49,645 square miles, The generally low run-off characteristic of this area may be brought out by analyzing it as follows:

TABLE 3
HISTORIC RUN-OFF OF STREAMS IN GULF COASTAL PLAIN PROVINCE
Units: 1,000 Acre-Feet

Stream	Drainage Area Sq. Mi.	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Red River below Denison Dam	3,640	1,932	3,025	3,455	1,689	2,612	6,886	4,714	2,288	2,084	2,788	4,299	2,329	1,712	2,475	1,797
Sulphur River	3,466	1,894	3,037	2,419	966	2,878	5,121	4,603	1,826	2,128	2,541	3,844	1,320	2,034	2,038	1,255
Cypress Creek	2,930	845	1,744	1,740	480	2,785	4,090	3,837	1,716	2,176	1,839	3,651	1,140	1,427	1,676	334
Sabine River	7,360	5,781	7,789	5,175	2,435	7,203	9,466	9,718	5,141	4,028	5,220	7,323	2,137	3,374	6,216	2,012
Neches River	9,175	7,443	9,483	5,363	2,175	8,987	9,004	10,974	6,568	3,458	5,976	8,571	1,659	3,120	6,898	1,668
Trinity River below Dallas	11,633	5,709	8,146	6,253	3,741	7,574	9,825	8,473	4,721	2,995	4,413	5,321	1,221	2,256	4,024	1,264
San Jacinto River	2,880	2,557	3,005	1,361	818	1,605	2,399	3,421	1,169	427	1,945	1,697	170	580	1,135	290
Brazos River Below Waco Excl. Little River	9,116	3,921	5,647	2,681	1,466	5,179	4,984	5,634	2,681	771	2,285	2,415	199	859	2,664	444
Colorado River below Austin	2,990	1,816	2,492	664	149	856	870	1,539	108	-*	732	400	-*	196	412	-*
Lavaca River & Coastal Area at Mouth	4,213	2,895	2,892	874	466	1,332	611	2,001	626	540	925	273	224	801	497	60
Guadalupe River below New Braunfels	8,221	1,703	2,261	1,744	494	737	804	2,099	718	343	1,083	373	364	570	672	110
Mission River	1,386	126	343	439	66	100	78	160	102	12	53	6	61	158	83	10

* Diversions and uses exceed inflow in reach

Historic run-off of streams in Gulf Coastal Plain province

Stream	Drainage Area Sq. Mi.	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Nueces River below Uvalde	13,847	907	1,188	1,212	174	693	449	1,242	300	70	651	193	371	173	548	170
Rio Grande below Del Rio	6,218	415	665	127	-*	540	-*	-*	-*	-*	-*	-*	-*	-*	-*	-**
Misc. Coastal drainage	11,990	3,074	6,405	3,466	2,676	3,912	3,467	6,024	2,214	839	3,559	2,609	615	1,546	2,245	849
TOTAL	106,099	41,018	58,122	36,973	17,795	46,993	58,054	64,439	30,178	19,961	34,009	40,975	11,810	18,806	31,583	10,263

*Diversions and uses exceed inflow in reach

** Storage of flood waters in Falcon Reservoir, diversion, and uses greatly exceed inflow in reach.

TABLE 4
DISTRIBUTION OF GULF COASTAL PLAIN PROVINCE
RUN-OFF BY BASINS

Units: As Shown

Stream	Average Annual Run-Off 1940-1954, 1000 Acre-Feet	Percent of Gulf Coastal Plain Run-Off
Red River (Denison Dam to Arkansas border)	2,939.0	8.5%
Sulphur River above state line	2,527.0	7.3
Cypress Creek above state line	1,965.3	5.7
Sabine River (Texas portion above mouth)	5,534.5	15.9
Neches River at mouth	6,095.7	17.6
Trinity River (Dallas to mouth)	5,062.4	14.6
San Jacinto River at mouth	1,505.3	4.3
Coastal Drainage from Sabine to Brazos River	2,311.0	6.6
Brazos River (Waco to mouth)	2,788.7	8.0
Colorado River (Austin to mouth)	682.3	2.0
Lavaca River at mouth	1,001.1	2.9
Guadalupe River (New Braunfels to mouth)	938.3	2.7
Mission River at mouth	119.8	0.3
Nueces River (Uvalde to mouth)	556.1	1.6
Rio Grande (Del Rio to mouth)	116.5	0.3
Misc. Coastal Drainage (Brazos to Rio Grande)	589.0	1.7
Total	34,732.0	100.0%

Area on the Gulf Coastal Plain	In terms of Gulf Coastal Plain Percent of Run-Off	Percent of Area
Red River to Brazos	88.5%	52.1%
Colorado to Rio Grande	11.5%	47.9%
Total	100.0%	100.0%

The northeast half of the Gulf Coastal Plain area in Texas furnishes 88.5 percent of the run-off from the Coastal Plain, leaving only 11.5 percent of the run-off that originates on the remaining half of the area.

There are several reasons why this larger run-off originates from the northeastern half of the Gulf Coastal Plain and not from the more southwesterly half. The most obvious reason is the difference in rainfall. Reference to the rainfall distribution as shown by Figure 4 indicates the average annual rainfall on the Gulf Coastal Plain north and east of the Brazos River varies from 35 to 56 inches.

In the more southerly half of the Gulf Coastal Plain (west of the Brazos) the average annual rainfall varies from 15 to 35 inches. This difference in rainfall does not account for the total difference in run-off from the respective areas, however.

Another significant factor on the amount of run-off is the evaporation. Wherever the evaporation is not offset by rainfall, the resulting losses of water (from any and all water surfaces or from the soil) can become serious. Reference is made to the Evaporation Map on Figure 7, which reflects net evaporation losses during periods of low rainfall. It is indicated that for the area on the Gulf Coastal Plain in Texas and East of the Brazos the net evaporation loss will range from about zero to 40 inches per year. Over the remaining half of the Coastal Plain (west of the Brazos River) the range is indicated to be from about 20 inches to 85 inches per year. Such a great difference in evaporation losses can be very effective in controlling the amounts of run-off.

There are probably other factors prominently effective in the differences between run-off from the respective areas, but their relationship to the problem is more obscure.

Central Texas Province

As shown on Figure 1, the Central Texas Province includes the area which is bounded by the Canadian and Red River on the north, the Gulf Coastal Plain on the east and south, and the Trans-Pecos and High Plains provinces on the west. The principal streams or appropriate portions thereof, their drainage areas, and their run-off by years are listed in Table 5. These are summarized in Table 6 which shows the average distribution of the run-off within this province with respect to area.

Unlike the streams which adjoin this area on the east, (not the south) the streams that cross this Central Texas Province are more erratic in flow. The base flow is or approaches zero in most parts of the geographic province, leaving the only appreciable run-off to be the direct result of storm rainfall.

In Table 2 of this report it was shown that 20.2 percent of the average annual run-off for the State for the period 1940-54 came from the Central Texas geographic province. Of the Central Texas run-off the Red River above Denison Dam accounts for 23.8 percent or almost one-quarter of the run-off. The Trinity River above Dallas, the Brazos River above Waco and its tributary the Little River above Cameron, plus the Colorado River above Austin account for an additional 61.6 percent of the run-off from this province. Thus only 14.6 percent of the run-off from this province comes from the area south and west of the Colorado River basin.

It can be equally well shown that most of the run-off in the Central Texas Province originates in the portion of the streams nearest the downstream limit of the zone rather than in the headwater areas. Reference is made to the charts showing the variation in annual run-off from the Brazos and Colorado River Drainage Basins, which are reflected by Figure 18 to Figure 22. These two basins account for nearly 47 percent of the run-off of the area for the 15-year period 1940-1954. The increase in depth of run-off as indicated for all of the charts above referred to, shows the rapid increase in rates of run-off in going from west to east.

An examination of the data contained in Table 6 once again shows the drainage areas in the eastern portion of the region to have much greater run-off than those to the west. The Little River on the southeast edge of the Central Texas Province has an average annual run-off of 1,222,300 acre-feet from an area of 7,034 square miles. This is three and one-half times the run-off of the sum of the Nueces River above Uvalde and its tributaries above the Balcones Escarpment, plus the Devils River on the western side which have a combined area of 7,248 square miles.

TABLE 5
HISTORIC RUN-OFF OF STREAMS IN CENTRAL TEXAS PROVINCE
Units: 1000 Acre-Feet

Stream	Drainage Area * Sq. Mi.	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Canadian River	8,393	67	1,305	227	32	149	56	341	72	165	423	362	300	1	127	146
Red River (above Denison Dam)	18,350	1,193	5,840	3,260	1,853	1,050	3,544	1,891	2,458	1,283	1,486	2,714	2,266	834	681	1,415
Trinity River (above Dallas)	6,120	1,119	2,800	3,267	695	999	2,884	2,061	822	894	1,333	2,021	347	179	233	115
Brazos River (Above Waco)	19,260	2,004	4,966	3,832	739	1,472	2,825	1,808	1,362	738	1,540	1,197	611	413	432	761
Little River (Above Cameron)	7,034	2,094	3,281	2,150	389	2,584	2,443	1,689	998	261	713	363	133	328	836	73
Colorado River (Above Austin)	26,490	1,499	3,708	1,346	1,414	1,508	1,760	1,644	1,261	910	958	809	693	558	673	669
Blanco River	364	50	214	86	37	131	123	118	71	16	45	18	10	112	55	13
San Marcos Springs	-	77	131	111	97	133	137	132	125	76	87	76	68	73	98	76
Guadalupe River (above New Braunfels, Incl. Comal Springs)	1,633	383	881	583	384	777	691	653	558	266	383	263	193	438	253	127
Frio River (Above Derby) **	3,493	18	155	70	25	47	41	58	20	32	70	2	62	1	88	19
Nueces River (above Uvalde)	1,947	13	31	41	12	14	7	23	15	38	192	10	2	3	10	54
Devils River	4,185	246	259	348	268	255	288	230	180	808	639	267	140	132	138	923
Total	-	8,763	23,571	15,321	5,945	9,119	14,799	10,648	7,942	5,487	7,869	8,102	4,825	3,072	3,624	4,391

* Exclusive of Non-Contributing areas
** Includes some area within The Coastal Plain

TABLE 6
DISTRIBUTION OF CENTRAL TEXAS PROVINCE
RUN-OFF BY BASINS

Units: As Shown

Stream	Average Annual Run-off 1940-1954 1000 Acre-Feet	Percentage of Central Texas Province Run-off
Canadian River	251.5	2.8%
Red River (Above Denison Dam)	2,117.9	23.8
Trinity River (Above Dallas)	1,317.9	14.8
Brazos River (Above Waco)	1,646.7	18.5
Little River (Above Cameron)	1,222.3	13.7
Colorado River (Above Austin)	1,294.0	14.6
Blanco River (Above Wimberley)	73.3	0.8
San Marcos Springs	99.8	1.1
Guadalupe River (Above New Braunfels Incl. Comal Springs)	455.5	5.1
Frio River (Above Derby)	47.2	0.5
Nueces River (Above Uvalde)	31.0	0.4
Devils River	341.4	3.9
Total	8,898.5	100.0 %

Trans-Pecos Texas Province

This province includes the area drained by the Rio Grande from El Paso to Del Rio exclusive of Devils River. The run-off from this area as shown in Table 2 averages 519,000 acre-feet per year during the fifteen-year period, which is only 1.2 percent of the total Texas run-off during this time. Rainfall in the region is low and the evaporation rates are the highest recorded in the State. Run-off is the result of intense rains of short duration. As an example the storm of June 27-28, 1954 produced the greatest flood peak of record on the Lower Pecos River, yet the volume was so small that all the flood waters were impounded in Falcon Reservoir.

All streams in the area are characteristically dry for long periods of time and run only after storm rainfall. The erratic nature of the stream flow can be determined by an analysis of the annual run-off as shown in Table 2. The minimum annual run-off from this area was 72,000 acre-feet in 1948, while the maximum was 1,330,000 acre-feet in 1954. In terms of percentage of the 15-year average, these figures are as follows:

Minimum - 13.9% of mean

Maximum -256.0% of mean

By comparison the maximum and minimum for the two other provinces of Texas, which furnish most of the run-off, are as follows:

	Gulf Coastal Plain	Central Texas Province
Minimum	29.5 % of mean	34.5 % of mean
Maximum	185.6 % of mean	265.0 % of mean

Development of the Rio Grande from its share of the tributary waters on the Gulf Coastal Plain in Texas has greatly expanded since Falcon Dam was completed in 1953. The additional international storage above Del Rio is already badly needed. Irrigation facilities in both the United States and Mexico below Falcon Reservoir, will effectively limit the future water supply that escapes into the Gulf of Mexico to the unavoidable wastes plus rare and unpredictable floods that originate below Falcon Dam.

Because of the meager run-off from this area, and its minor importance to the rest of the state, there has been no comparable breakdown of the figures such as was done for the two main runoff-producing areas nearer the coast.

High Plains Province

Of the four geographic provinces of Texas this area is unique in that it furnishes very little run-off to river basins to the east and to the south. Such portions of the area above the Cap Rock that may contribute to the run-off of the Canadian, Red, Brazos and Colorado River Basins are included in the areas of these basins listed in the Central Texas province.

Surface run-off that occurs in this region usually terminates in small nautral depressions or sinks. The water so stored is soon dissipated either by evaporation or as recharge to the groundwater. For these reasons the area is said to be non-contributing. The surface run-off of the province has been taken as zero.

Recapitulation on Run-Off from Texas
From the Four Geographic Provinces

A recapitulation of the run-off of Texas in relation to the areas from which it comes has been prepared as Table 7. The percentage figures with respect to both run-off and drainage area are given in terms of the total run-off from the four geographic provinces of the State, and the total land area of the state.

It has been previously shown that 69.5 percent of all of the run-off observed in Texas in the past 15 years comes from 20.6 percent of the land areas of the State. This area is generally the eastern portion of the state, extending from the Gulf of Mexico to the Red River. If there be added to this area the run-off from Trinity River above Dallas, plus Little River above Cameron, the percentage figures increase as follows: (Reference - Table 7)

Run-Off Area	% of Total Run-Off	% of Total Area
Sabine to Brazos below Waco and from Gulf to Red River	69.5%	20.6%
Trinity River above Dallas	3.0	2.3
Little River above Cameron	2.8	2.7
Sub-total	75.3%	25.6%

It may be noted that about three-quarters of all the run-off originating in Texas, as indicated by the records for the last 15-year period, was produced from one-quarter of the State's area. From this it should be quite clear that any average figures on run-off from the State of Texas, wherein the state is used as a homogeneous body, are wholly meaningless. In terms of water, and area, the same thing can be said as follows:

Out of the total run-off of 44,150,000 acre-feet, which is the average for such a period as 1940-1954, about 33,000,000 acre-feet came from an area of 66,000 square miles in the eastern part of the State. The remaining area of approximately 198,000 square miles thus produces on the average only about 11,000,000 acre-feet of run-off per year. The ratio of run-off to area from these two component parts is:

East Texas 33,000,000/ 66,000 = 500 AF/sq. mi.

Remainder of State 11,000,000/198,000 = 56 AF/sq. mi.

This ratio is about nine to one in favor of East Texas.

A check on the run-off figures for the last four-year period in the record, 1951-54, shows that this same relationship of run-off with respect to area holds as was found for the longer period.

Although the run-off is great from this 25 percent of the area of the State, the rate of run-off from even this relatively small portion of the state is by no means uniform over that area. Records of the run-off from small drainage areas within the eastern part of the state show that the average run-off varies from about 3 inches in depth along the western limit of this area to more than 15 inches near the Louisiana border.

TABLE 7
RUN-OFF FROM TEXAS - AVE. 1940-1954 INCL.

	Run-off			Drainage Area		
	1000 A.F.	% of Tot. R.O.		Sq. Mi.	% of Tot. Land Area	
Gulf Coastal Plain		%	Accum. %		%	Accum. %
Red Rr. b/l Denison Dam	2939.0	6.7	6.7	3640	1.4	1.4
Sulphur Rr. to State Line	2537.0	5.7	12.4	3466	1.3	2.7
Cypress Cr. to State Line	1965.3	4.4	16.8	2930	1.1	3.8
Sabine Rr. in Tex. only	5534.5	12.5	29.3	7360	2.8	6.6
Neches Rr.	6095.7	13.8	43.1	9175	3.5	10.1
Trinity R. b/l Dallas	5062.4	11.5	54.6	11633	4.4	14.5
San Jacinto Rr.	1505.3	3.4	58.0	2880	1.1	15.6
Coastal Drainage Sabine to Brazos	2311.0	5.2	63.2	3920	1.5	17.1
Brazos Rr. b/l Waco	2788.7	6.3	69.5	9116	3.5	20.6
Colorado Rr. b/l Austin	682.3	1.5	71.0	2990	1.1	21.7
Lavaca Incl. Navidad plus Coastal Drainage	1001.1	2.3	73.3	4213	1.6	23.3
Guadalupe Rr. b/l New Braunfels	938.3	2.1	75.4	8221	3.1	26.4
Mission Rr. incl. Coastal Drainage	119.8	0.3	75.7	1386	0.5	26.9
Nueces Rr. b/l Uvalde	556.1	1.2	76.9	13847	5.3	32.2
Rio Grande b/l Del Rio	116.5	0.3	77.2	6218	2.4	34.6
Misc. Coastal Drainage	589.0	1.4	78.6	8070	3.0	37.6
Non-Contributing Coastal Area	0	0	78.6	4700	1.8	39.4
Totals	34732.0			103765		
Central Texas Province						
Canadian River	251.5	0.6	79.2	8393	3.2	42.6
Red Rr. above Denison Dam	2117.9	4.8	84.0	18350	7.0	49.6
Trinity River above Dallas	1317.9	3.0	87.0	6120	2.3	51.9
Brazos River above Waco	1646.7	3.7	90.7	19260	7.3	59.2
Little River above Cameron	1222.3	2.8	93.5	7034	2.7	61.9
Colorado River above Austin	1294.0	2.9	96.4	26490	10.0	71.9
Blanco River	73.3	0.2	96.6	364	0.1	72.0
San Marcos Springs	99.8	0.2	96.8	-	0	72.0
Guadalupe Rr. above New Braunfels(incl. Comal Spgs.)	455.5	1.0	97.8	1633	0.6	72.6
Frio River	47.2	0.1	97.9	613	0.2	72.8
Nueces Rr. & Tributaries	31.0	0.1	98.0	2450	0.9	73.7
Devils River	341.4	0.8	98.8	4185	1.6	75.3
Totals	8898.5			94892		
Trans-Pecos Texas						
Rio Grande above Del Rio)	519.0	1.2	100.0	14005	5.3	80.6
Pecos River				15753	6.0	86.6
Non-Contributing	0	0	100.0	8284	3.2	89.8
Totals	519.0			38042		
High Plains						
Totals	0		100.0	26945	10.2	100.0

Inflow from Adjoining States and Outflow to Adjacent States

The three principal streams which enter Texas from New Mexico on the western side of the State are the Rio Grande at El Paso; the Pecos River about 45 miles above Pecos, Texas; and the Canadian River with some of its tributaries entering north and west of Amarillo.

The flow of the Rio Grande above El Paso is largely controlled by the Elephant Butte Reservoir (capacity 2,185,400 acre-feet) and Caballo Reservoir (capacity 340,900 acre-feet). These reservoirs supply water for the irrigation of lands in New Mexico, Texas, and Mexico. Mexico receives a maximum of 60,000 acre-feet of water per year under the provisions of the 1906 treaty between the two countries. Irrigation in El Paso and Hudspeth Counties makes full use of the available supply, with the exception of very infrequent reservoir spills.

Red Bluff Dam located on the Pecos River in Reeves County just below the Texas-New Mexico boundary provides 270,000 acre-feet of conservation storage capacity. Water stored in the reservoir is used for the irrigation of lands in the Red Bluff Water Power Control District. Full use is made of the available supply of water, except during the times of infrequent reservoir spill or during periods in which the high salt concentration precludes its use.

At present the intermittent flows of the Canadian River and its tributaries are largely unused in Texas. A proposal for the construction of a large reservoir project at the Sanford Dam Site north of Amarillo has been under study for several years. With the advent of such a project to provide municipal water to Panhandle and High Plains cities the flow of this stream will also largely be put to use. By that time the flow of all three streams which enter Texas from New Mexico will be, for all intents and purposes, completely utilized. The sum of the total inflow by years from these three streams is contained in Table 8. The average for the fifteen year period was 979,000 acre-feet.

Four streams furnish run-off from drainage areas in Texas to downstream states. These streams and the states they enter are:

Canadian River (including the North Canadian)	- Oklahoma
Red River	- Arkansas
Sulphur River	- Louisiana
Cypress Creek	- Louisiana

Data in Table 1 show the total area in the State in these four basins to be 46,364 square miles, or 17.6 percent of the total land area of the state.

The sum of the annual outflows of the four streams is given by years in Table 8, together with the differences between inflows to the State and the outflows. These data are shown graphically on Figure 9. A furthur breakdown of the inflow and outflow is given in Table 9. The total run-off of the four streams for the fifteen-year period averaged 10,003,000 acre-feet, which is about 9,000,000 acre-feet more than enters the state. Of particular importance is the location of this excess water. Most of it originates in the northeastern portion of the state on the Gulf Coastal Plain. As previously explained the total flow of the Red River has not been used in this computation, only 50% of it being credited to Texas.

TABLE 8
SUMMARY OF INFLOW TO TEXAS FROM ADJOINING STATES AND OUTFLOW TO ADJACENT STATES

Units: Acre-Feet

Year	Water Entering Texas	Water Flowing to Adjacent Downstream States	Excess Over Inflows
1940	579,000	5,948,000	5,369,000
1941	3,730,000	16,519,000	12,789,000
1942	3,054,000	12,121,000	9,067,000
1943	837,000	5,073,000	4,236,000
1944	886,000	8,672,000	7,786,000
1945	696,000	19,729,000	19,033,000
1946	711,000	15,500,000	14,789,000
1947	606,000	8,435,000	7,829,000
1948	640,000	7,946,000	7,306,000
1949	716,000	9,166,000	8,450,000
1950	766,000	14,988,000	14,222,000
1951	391,000	7,421,000	7,030,000
1952	368,000	6,040,000	5,672,000
1953	347,000	7,044,000	6,697,000
1954	359,000	5,448,000	5,089,000
Average	979,000	10,003,000	9,024,000

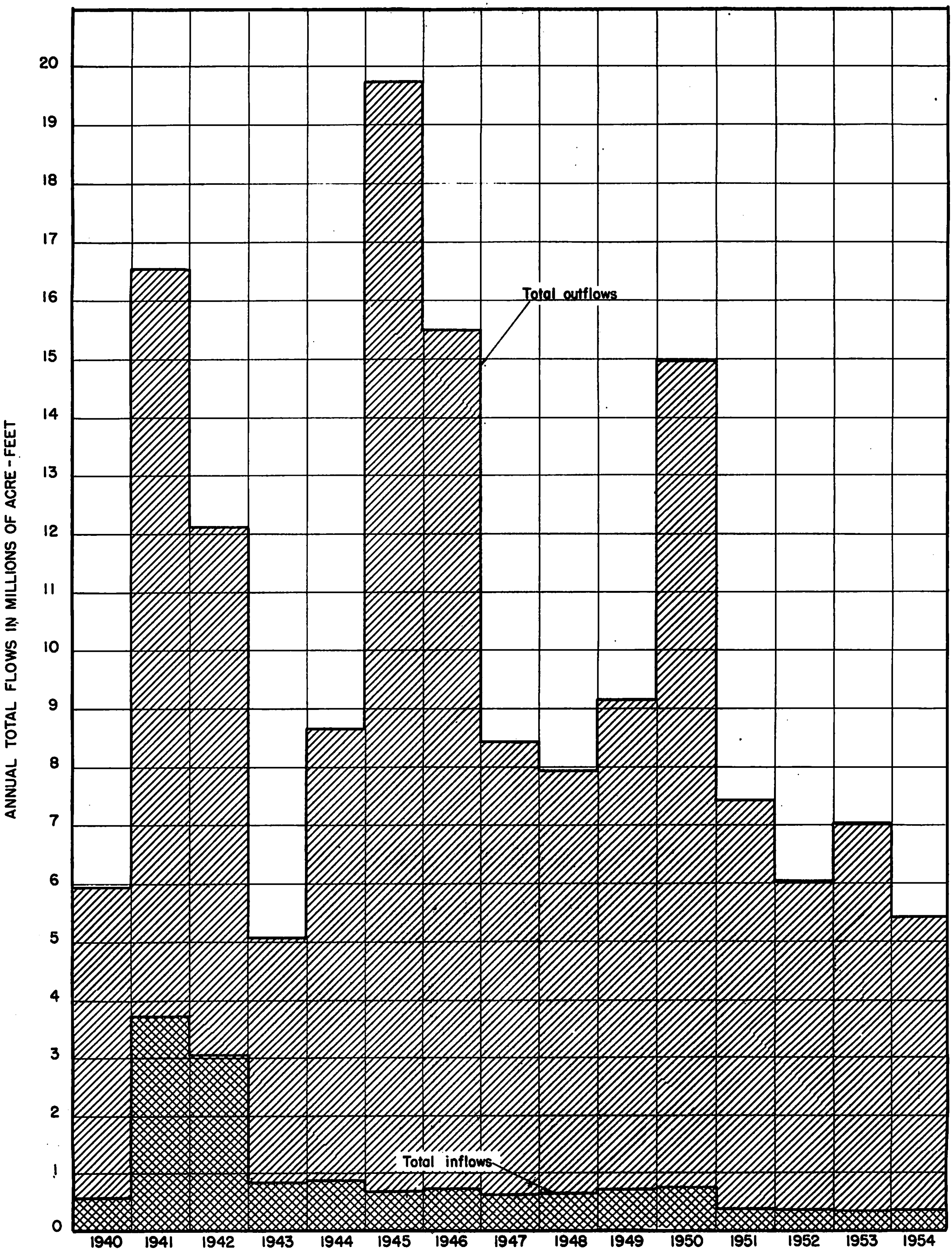


FIGURE - 9

ANNUAL INFLOWS FROM ADJOINING STATES AND OUTFLOWS TO ADJACENT STATES

TABLE 9
INFLOW TO TEXAS FROM ADJOINING STATES
AND OUTFLOW TO ADJACENT STATES
Units: 1000 Acre-Feet

	Inflow				Outflow					Outflow in Excess of Inflows
Year	Rio Grande	Pecos	Canadian	Total	Red*	Sulphur	Cypress	Canadian	Total	
1940	453.9	108.1	17.3	579.3	3125.0	1894.0	845.0	84.0	5948.0	5,368.7
1941	511.4	1650.7	1568.0	3730.1	8865.0	3037.0	1744.0	2873.0	16519.0	12,788.9
1942	1559.2	474.5	1020.0	3053.7	6715.0	2419.0	1740.0	1247.0	12121.0	9,067.3
1943	631.8	153.0	52.3	837.1	3542.0	966.0	480.0	84.7	5072.7	4,235.6
1944	611.9	125.7	148.1	885.7	2712.0	2878.0	2785.0	297.2	8672.2	7,786.5
1945	568.9	95.4	32.0	696.3	10430.0	5121.0	4090.0	88.1	19729.1	19,032.8
1946	497.9	99.1	114.1	711.1	6605.0	4603.0	3837.0	455.2	15500.2	14,789.1
1947	458.9	72.0	75.5	606.4	4746.0	1826.0	1716.0	147.2	8435.2	7,828.8
1948	431.7	98.4	110.4	640.5	3367.0	2128.0	2176.0	275.0	7946.0	7,305.5
1949	463.5	163.5	89.4	716.4	4274.0	2541.0	1839.0	512.2	9166.2	8,449.8
1950	472.6	176.6	117.1	766.3	7013.0	3844.0	3651.0	479.5	14987.5	14,221.2
1951	252.0	72.9	66.4	391.3	4595.0	1320.0	1140.0	366.2	7421.2	7,029.9
1952	283.7	50.2	33.8	367.7	2545.0	2034.0	1427.0	34.7	6040.7	5,673.0
1953	264.5	36.3	46.3	347.1	3156.0	2038.0	1676.0	173.3	7043.3	6,696.2
1954	93.7	227.1	38.0	358.8	3212.0	1255.0	797.5	184.0	5448.5	5,089.7
Average	503.7	240.2	235.3	979.2	4993.5	2526.9	1996.2	486.7	10003.3	9,024.1
% of Total	51.4	24.6	24.0	100.0%	49.9	25.3	20.0	4,8	100.0%	-

* Taken as 50% of Total Flow

Although average figures have been given above in regard to these inflows and outflows, the averages mean very little because of the wide range through which the annual flow has varied. The water entering Texas from New Mexico has averaged 979,000 acre-feet. However, the figures in Table 8 show that fully 46 percent of the total inflow for the period was incident to the flood run-off of 1941 and 1942. It is also indicated that the carryover storage in New Mexico reservoirs was exhausted by the end of 1950, and the total inflow since that time has averaged only about 366,000 acre-feet per year for the last 4 years, which is only 37 percent of the longer average.

The water leaving the State was largely concentrated within the 10-year period, 1941 through 1950, during which the average annual outflow was 11,815,000 acre-feet. In the last four years this average has dropped to 6,488,000 acre-feet per year, which is only about 65 percent of the 15-year average.

Analyzed another way, the variation in annual flow can be shown as follows:

	Maximum Annual Flow			Minimum Annual Flow		
	1000 A.F.	% of Av.	Year	1000 A.F.	% of Av.	Year
Water Entering Texas	3,730.0	381	1941	347.0	35	1953
Water Flowing to downstream States	19,729.0	197	1945	5,073.0	51	1943

Flow into Gulf of Mexico

Considerable discussion and publicity during the past and present has centered on the flow of Texas streams annually lost to the Gulf of Mexico. The immediately preceding section considered the run-off of the Canadian, Red, and Sulphur Rivers and Cypress Creek.

All other streams of the State discharge into the Gulf of Mexico, and of these the run-off is given in Table 10 and shown graphically on Figure 10. These data are summarized on Table 11. An average annual flow into the Gulf of 34,354,800 acre-feet during the 15-year period, 1940 to 1954 is indicated. These tabulations are arranged with the streams in order of occurrence from east to west. It is noted that the flow of the Sabine used herein is that portion allocated to Texas by the Sabine River Compact and not the total flow of the stream. The four streams, Sabine, Neches, Trinity and Brazos Rivers, had a total average annual flow into the Gulf during this period of 23,650,200 acre-feet, or 68.8% of the total flow into the Gulf.

Recent storage developments are not fully reflected in these data. Reservoirs in the upper Trinity, Brazos, Colorado, San Jacinto, and Rio Grande, which have been created in recent years, will reduce to some extent the amounts of water flowing into the Gulf in the future. Proposed projects on the Neches, Sabine, Brazos, Guadalupe and Nueces Rivers will further reduce the amounts when these developments take place.

In 1954 the flow of the Texas portion of the Rio Grande into the Gulf was 76,000 acre-feet which is only 7.6 percent of the fifteen-year average. This water was the unavoidable waste water from irrigation and small floods originating below Falcon Dam. The future Rio Grande flows into the Gulf are not expected to be greatly different from the flow of 1954.

TABLE 10
FLOW OF TEXAS STREAMS INTO GULF OF MEXICO
Units: 1000 Acre-Feet

Stream	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Sabine	5,781	7,789	5,175	2,435	7,203	9,466	9,718	5,141	4,028	5,220	7,323	2,137	3,374	6,216	2,012
Neches	7,443	9,483	5,363	2,175	8,987	9,004	10,974	6,568	3,548	5,975	8,571	1,659	3,120	6,898	1,66[illegible]
Trinity	6,828	10,946	9,520	4,166	8,573	12,709	10,534	5,543	3,889	5,746	7,342	1,568	2,435	4,257	1,379
San Jacinto	2,557	3,005	1,361	818	1,605	2,399	3,421	1,169	427	1,945	1,697	170	580	1,135	290
Brazos	8,019	13,894	8,663	2,594	9,235	10,252	9,131	5,041	1,770	4,538	3,975	943	1,600	3,932	1,278
Colorado	3,315	6,200	2,010	1,563	2,364	2,630	3,183	1,752	895	1,690	1,209	619	754	1,085	479
Lavaca	2,895	2,892	874	466	1,332	611	2,001	626	540	925	273	224	801	497	60
Guadalupe	2,213	3,488	2,524	1,013	1,777	1,755	3,003	1,472	701	1,598	729	635	1,194	1,078	326
Nueces	938	1,374	1,324	212	754	497	1,323	335	139	913	205	435	177	646	244
Rio Grande	1,320	2,763	2,621	831	1,554	863	964	628	955	1,261	341	310	93	327	76
Misc. Coastal*	3,200	6,748	3,905	2,742	4,011	3,544	6,183	2,316	852	3,612	2,615	676	1,704	2,328	858
Total	44,509	68,582	43,340	19,015	47,395	53,730	60,435	30,591	17,744	33,423	34,280	9,376	15,832	28,399	8,670

* Includes Mission River

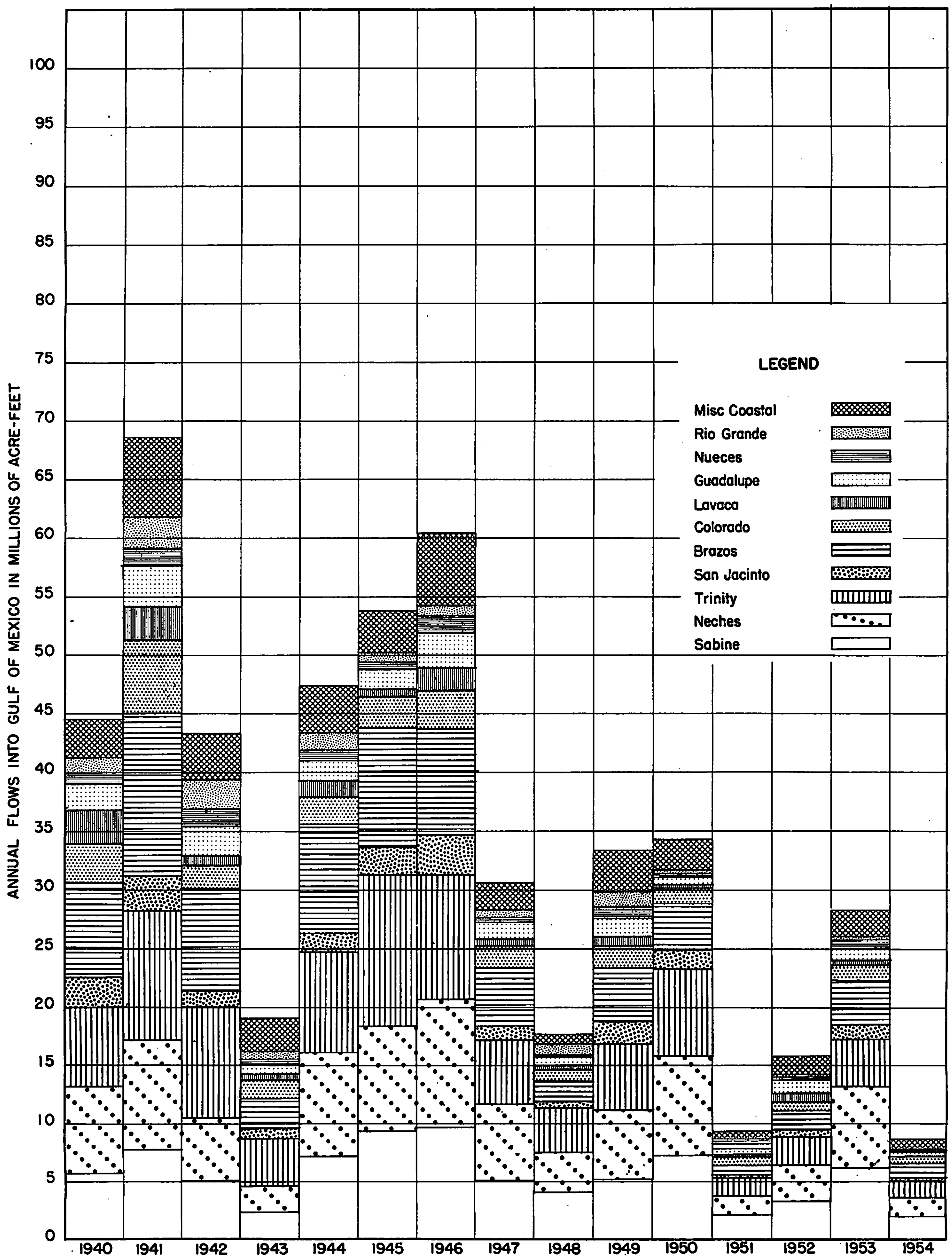


FIGURE-10

ANNUAL FLOWS INTO GULF OF MEXICO BY DRAINAGE BASINS IN TEXAS

TABLE 11
DISTRIBUTION OF RUN-OFF INTO
GULF OF MEXICO BY STREAMS

Units: As Shown

Stream	Average Annual Run-Off 1940-1954 1000 Acre-Feet	Percentage of Total Runoff into Gulf
Sabine (Texas only)	5,534,5	16.1 %
Neches	6,095.7	17.7
Trinity	6,362.3	18.5
San Jacinto	1,505.3	4.4
Brazos	5,657.7	16.5
Colorado	1,983.2	5.8
Lavaca	1,001.1	2.9
Guadalupe	1,567.1	4.6
Nueces	634.3	1.8
Rio Grande (Texas only)	993.8	2.9
Misc. Coastal *	3,019.8	8.8
Total	34,354.8 **	100.0 %

* Including Mission River

** This figure does not include the run-off from the Canadian, Red, and Sulphur rivers, nor the run-off from Cypress Creek.

Charts of Monthly Run-off of Selected Rivers

Seven of the principal rivers of Texas have records of run-off sufficiently long to present a good picture of the variability with which run-off occurs. This variability is present in relation to location, as well as with respect to time. The following streams were selected to show this great variability, simply because their records of stream flow cover a common period, which in this case, is the last 30 years:

Sabine River near Ruliff
Neches River at Evadale
Trinity River at Romayor
Brazos River at Richmond
Colorado River at Columbus
Guadalupe River at Victoria
Nueces River near Three Rivers

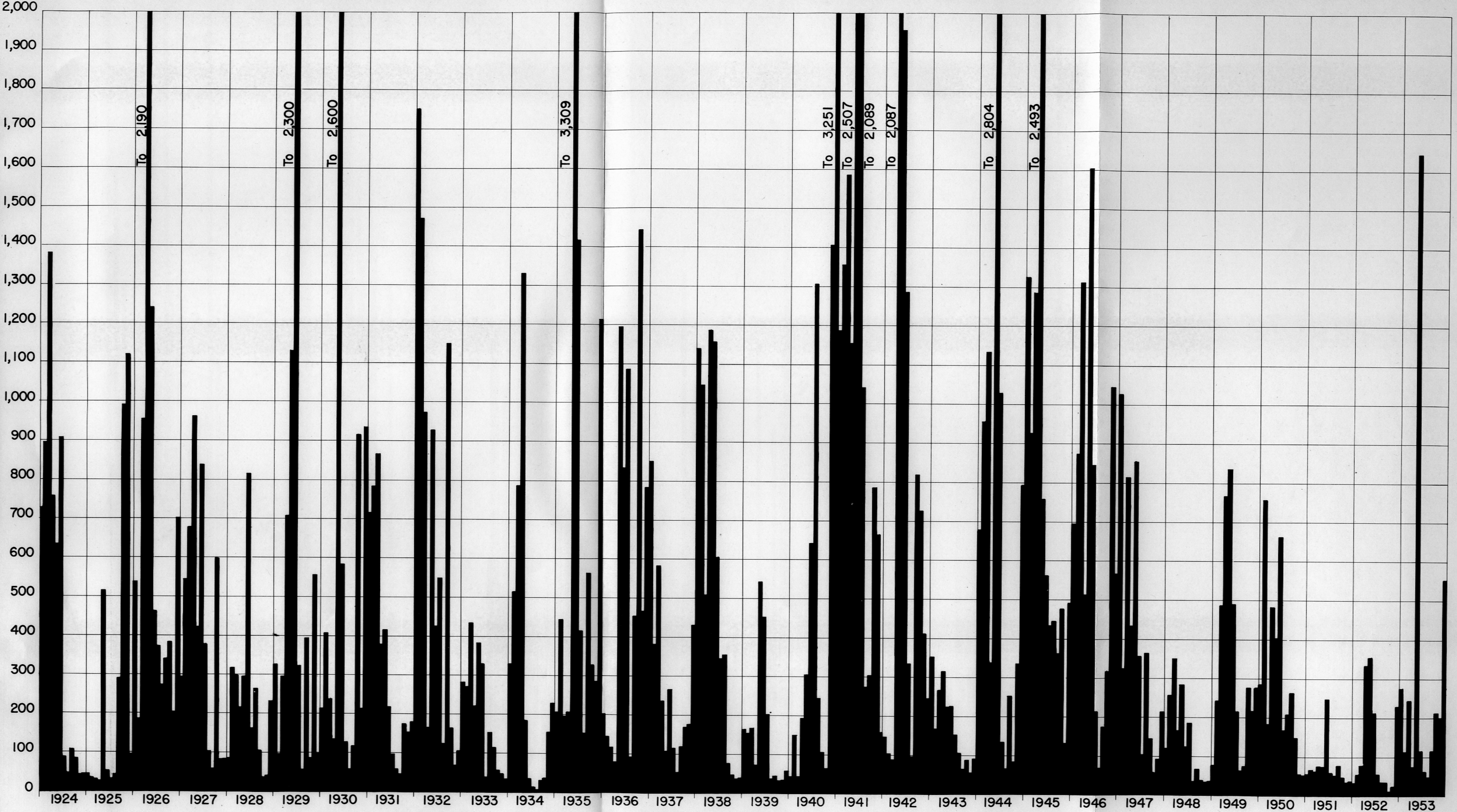
A separate chart showing the monthly run-off since 1924 for each of these streams has been prepared, as shown by Figures 11, 12, 13, 14, 15, 16, and 17.

These charts reflect the monthly run-off as recorded by the U. S. Geological Survey. The plotting is made without regard to the size of the drainage area that contributed to the run-off. For instance, the Brazos River Basin contains the greatest drainage area of any stream in Texas. However, a visual comparison of the charts shows that it does not furnish the greatest run-off to the Gulf, being exceeded by the Sabine, Neches, and Trinity River basins, all of which are much smaller in area.

During the 30-years covered by the study there have been changes in the water use on the watersheds. This is best portrayed by the chart depicting the monthly run-off of the Colorado River (Figure 15). Prior to about 1938 there was a relatively small amount of storage on the river. However, within the next few years a large amount of storage was created on the stream, incident to the development of the Lower Colorado River Authority. The effect of this storage capacity is reflected on the chart, wherein the regulated flow since about 1938 contrasts noticeably with the unregulated flow which prevailed prior to that time.

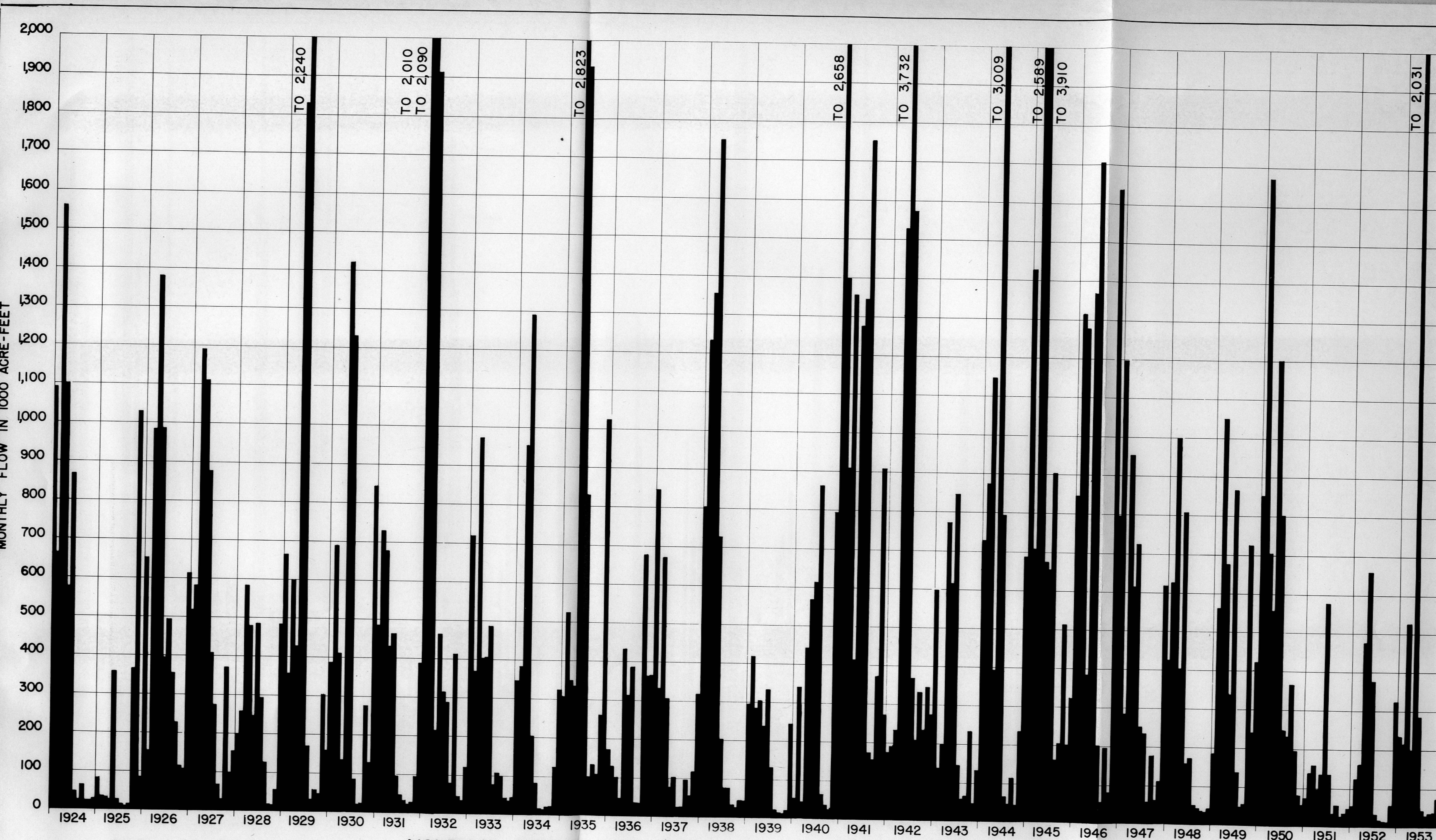
The pattern of flows shown on this chart for the last decade is indicative of the monthly distribution of water demands for hydro-electric power generation.

Regulation has also been provided on other streams within the study period. This is particularly true in the Brazos River Basin, where the following major reservoirs have been built: Possum Kingdom, Whitney, and Belton. Within this period Denison Dam was built on the Red River. Many headwaters reservoirs have likewise been constructed in the Trinity River Basin--some of them of such recent date that they are not reflected in the records portrayed on the charts. The monthly discharge of the Trinity River at Romayor, as shown by Figure 13, reflects the effect of the sewage effluent from Fort Worth and Dallas in maintaining the low flow. Reservoirs are now under construction which will further modify the picture on many of these streams as it is projected into the future.



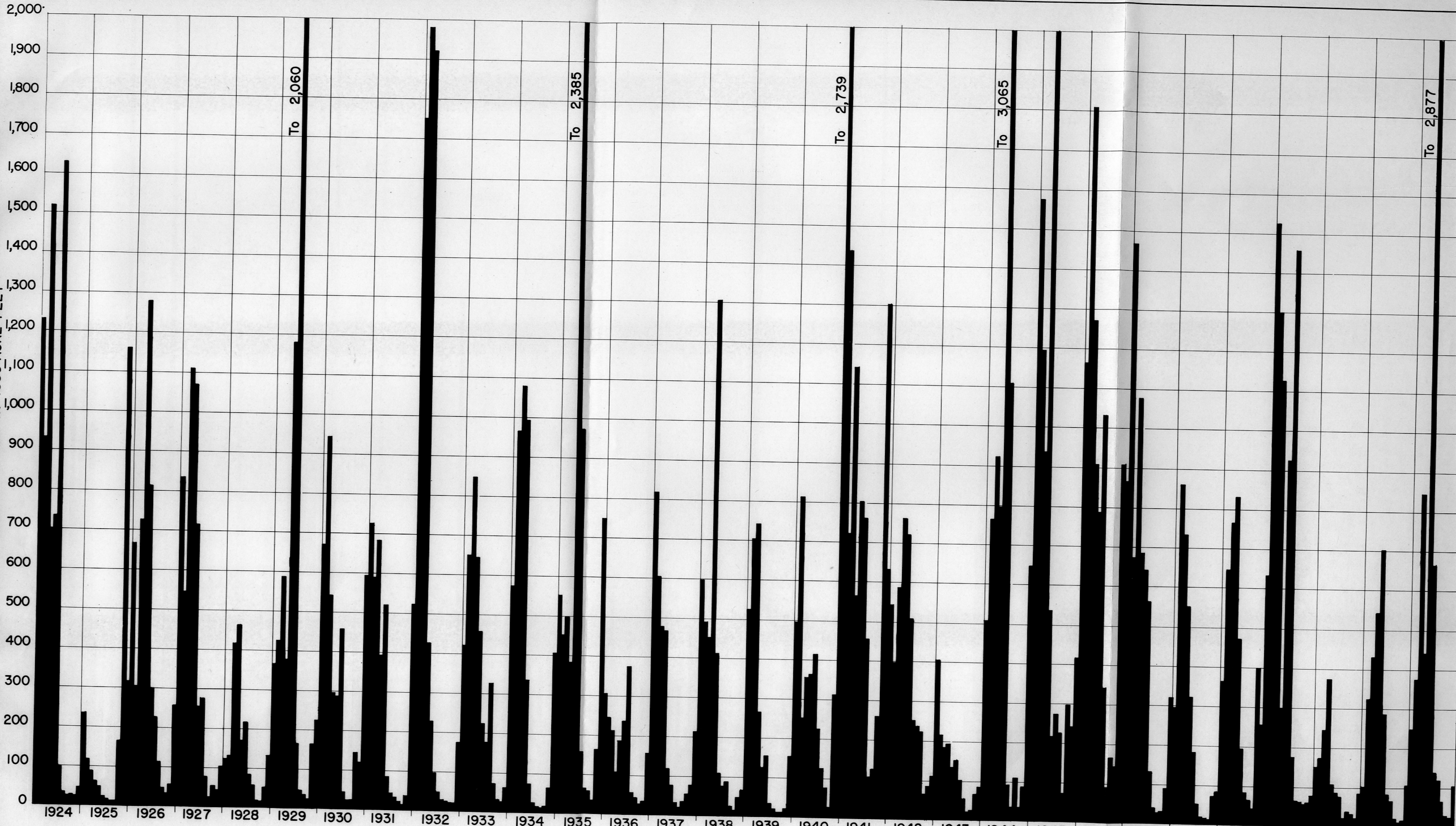
MONTHLY RUNOFF OF BRAZOS RIVER AT RICHMOND 1924-1953

FIGURE-14



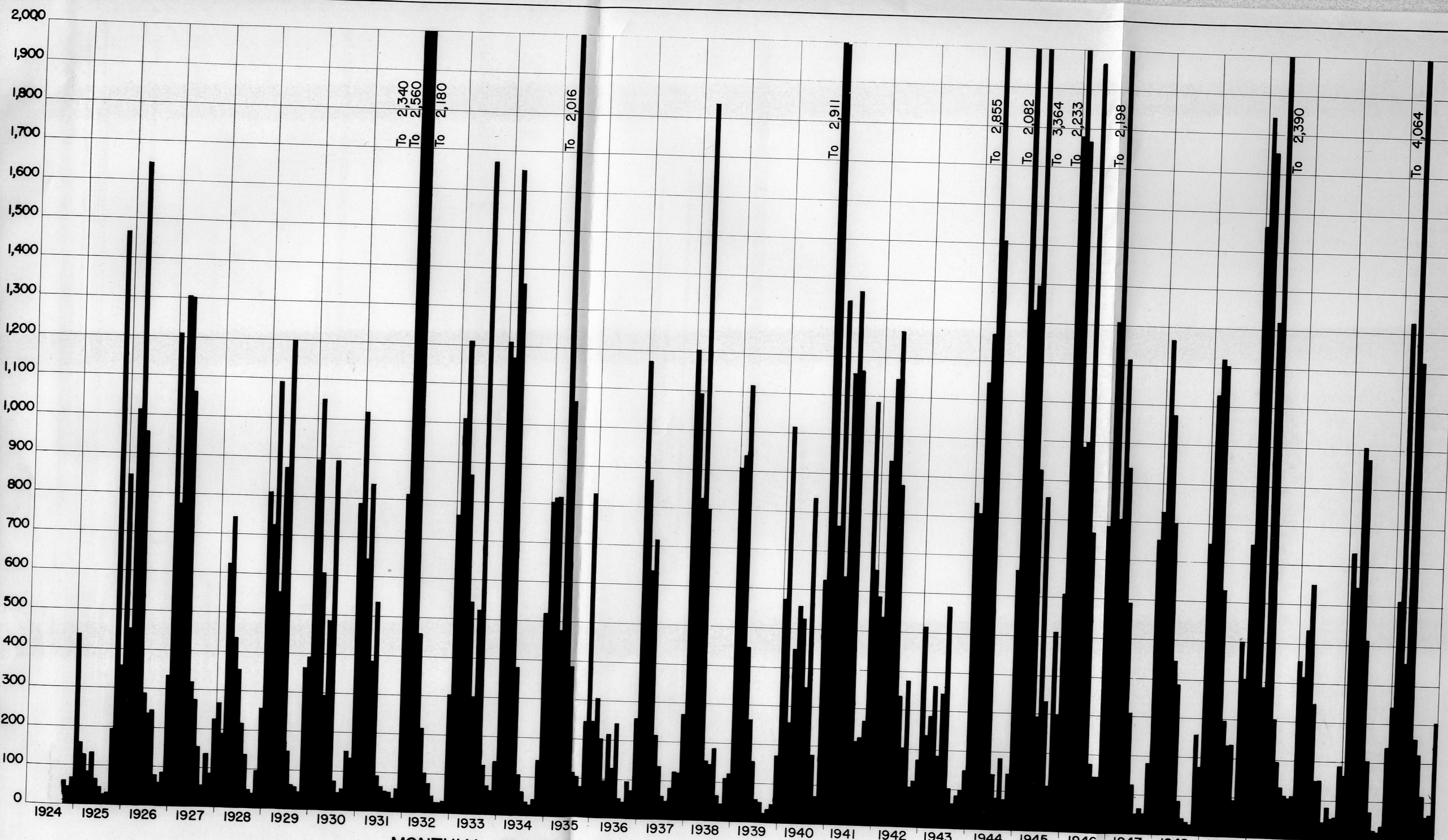
MONTHLY RUNOFF OF TRINITY RIVER AT ROMAYOR 1924-1953

FIGURE



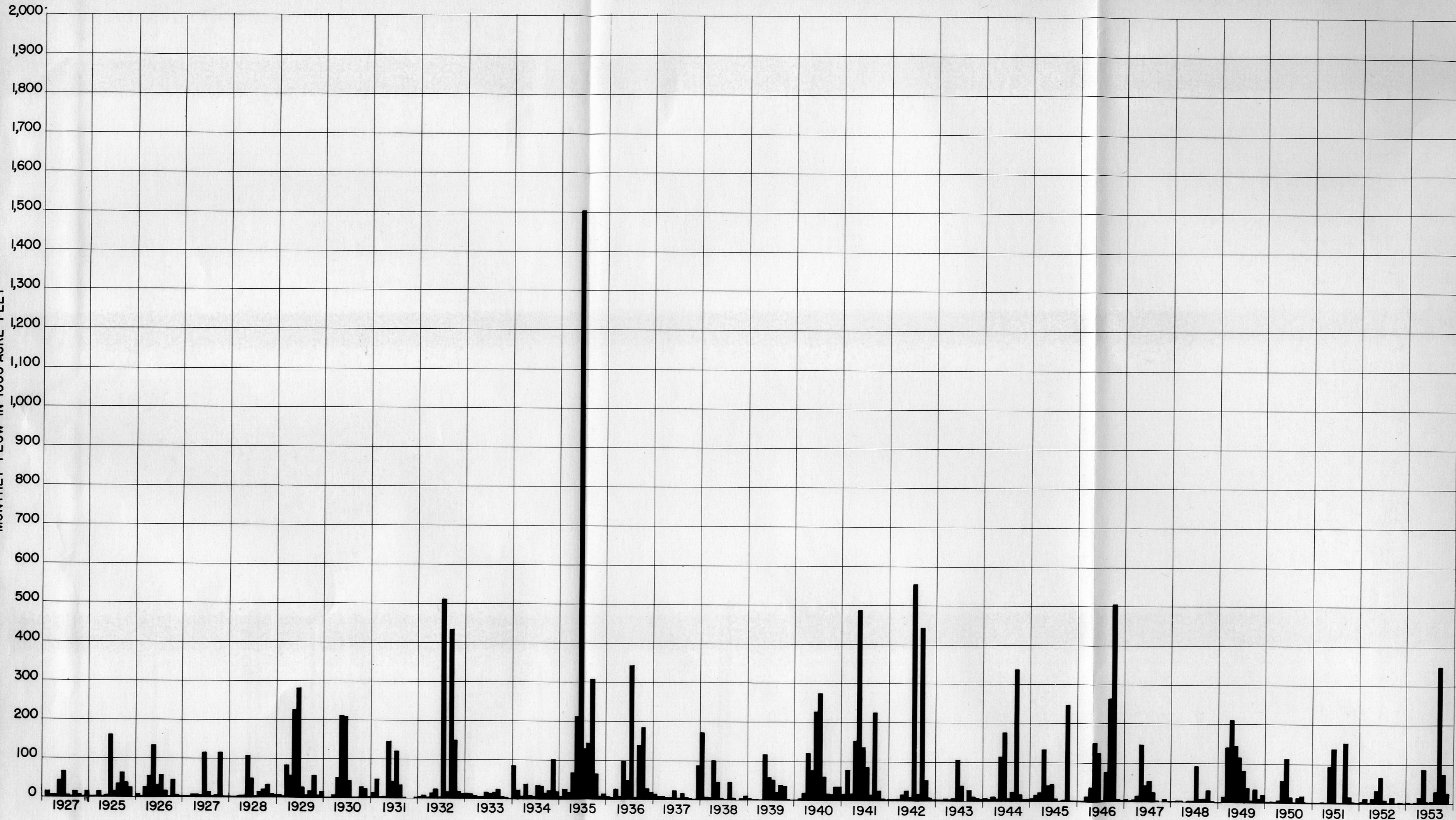
MONTHLY RUNOFF OF NECHES RIVER AT EVADALE 1924-1953

FIGURE



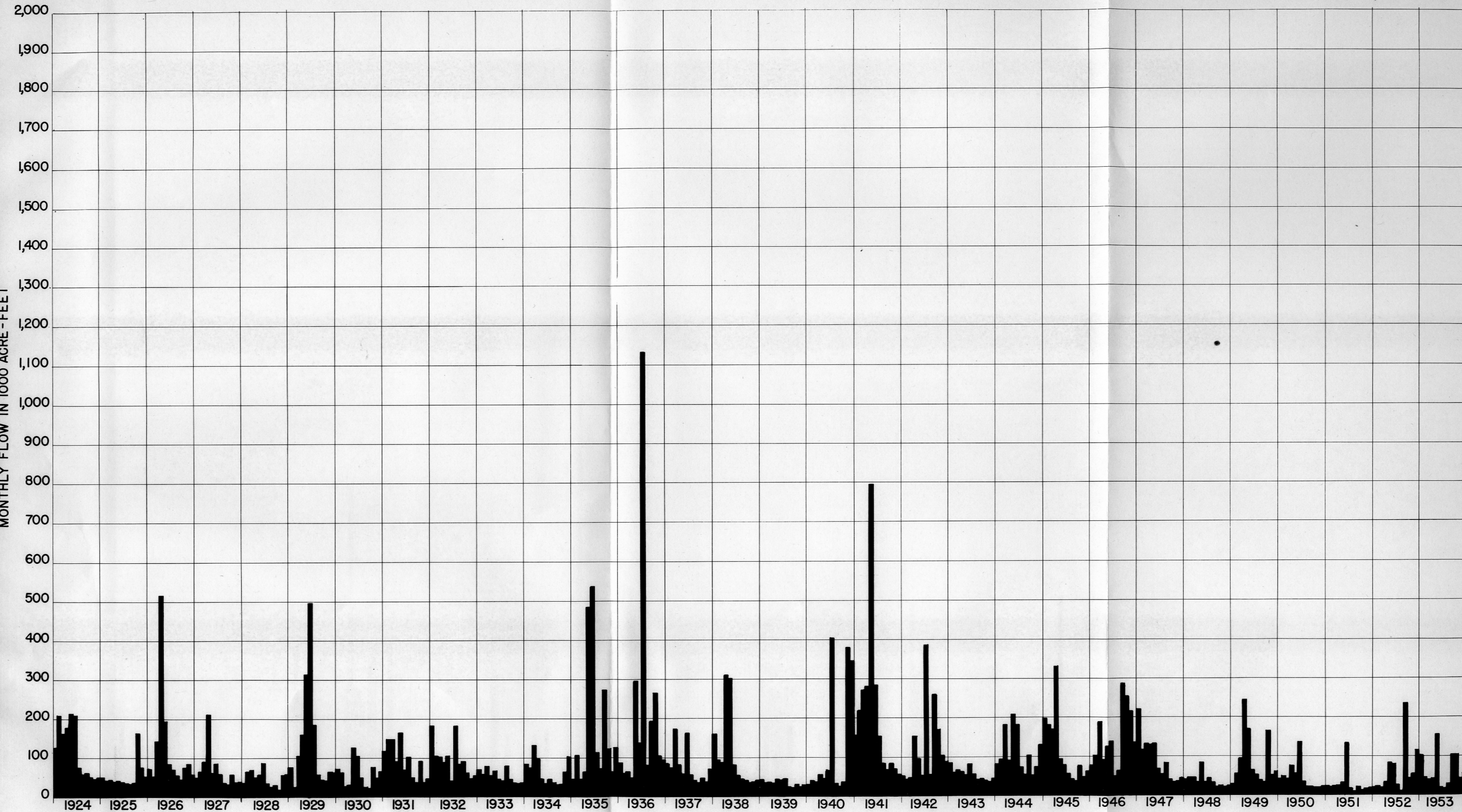
MONTHLY RUNOFF OF SABINE RIVER NEAR RULIFF 1924-1953

FIGURE - I



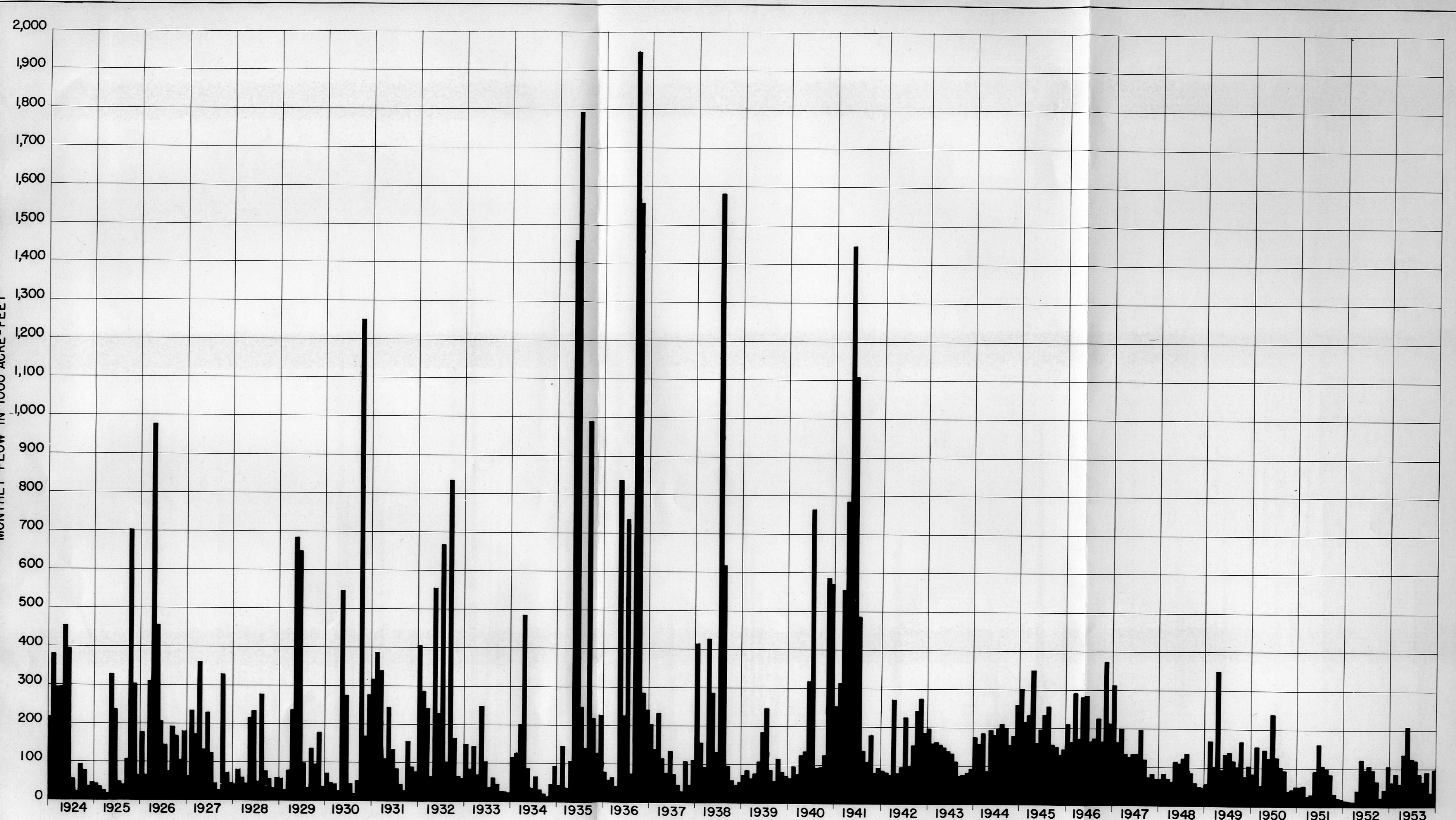
MONTHLY RUNOFF OF NUECES RIVER NEAR THREE RIVERS 1924-1953

FIGURE-17



MONTHLY RUNOFF OF GUADALUPE RIVER AT VICTORIA 1924-1953

FIGURE - 16



COLORADO RIVER AT COLUMBUS 1924-1953

FIGURE-15

Together, these streams comprise a total area of about 119,000 square miles, exclusive of the areas at the upper ends of the Brazos and Colorado Rivers which do not contribute to the run-off. The respective areas drained by these streams at the aforementioned gaging stations and their average annual run-off for the 30-year period are shown in the following tabulation:

Stream	Contributing Drainage Area Square Miles	Average Annual Run-off 1000 Acre-Feet	Inches
Sabine *	9,440	6,655.8	13.23
Neches	7,908	4,833.6	11.46
Trinity	17,192	5,596.9	6.10
Brazos	34,810	5,374.4	2.90
Colorado	29,170	2,319.3	1.49
Guadalupe	5,311	1,136.5	4.01 **
Nueces	15,600	591.7	0.71

* Figures shown in this tabulation are in reference to the gaging stations and are not in terms of the water credited to Texas as used elsewhere in this report.

** If Comal and San Marcos Springs are omitted this value is reduced to about 2.8 inches.

The average stream flow is of no importance so far as future potential use is concerned, but it is shown here simply for comparison. The streams along the eastern border of the State show that annually there is an average run-off of 13.23 inches (Sabine River). On the other side of the state (the Nueces River) the average run-off is only a fraction of an inch. Both of these streams lie on the Coastal Plain. The great difference in the depth of run-off obviously results largely from the difference in rainfall.

The significant feature of the charts is that they show the great variability in the run-off from month to month and from year to year. While the daily discharge is not shown, there is a much wider fluctuation in it. Low flow, except for sewage effluent in some instances, is controlled by the ground-water accretion, while extreme flood discharge on the other hand is a measure of the storm run-off. It should be pointed out that storms of equal intensity may occur in any of the watersheds of Texas, but the frequency of their occurrence is quite different from place to place. Also it should be pointed out that rates of run-off from the respective areas are greatly affected by the vegetative cover, soil type, and the topography.

As indicated above, the average run-off from each separate drainage area means nothing in itself, because of the wide differences in run-off characteristics within various parts of the same basin. The Brazos River is a good example in this respect. The run-off from thousands of square miles in the headwaters area is zero. Run-off starts in general below the Cap Rock and increases towards the mouth. For a hundred miles downstream from the Cap Rock, the run-off can be measured in terms of a fraction of an inch in depth. However, near the mouth, say in the lower one hundred miles, the average annual run-off is more than six inches in depth. The same general characteristics with respect to run-off prevail in all of the watersheds.

Run-off for long periods will be only the accretions from ground-water, which in some areas is zero. Then suddenly a flood will result from storm rainfall, and high rates of run-off will occur for a period of a few days. Past evidence shows clearly that extreme rates of run-off for short periods of time are much greater toward the southwest, no doubt reflecting the absence of the dampening effect of the heavy vegetative cover in the eastern part of the State.

The variability is further emphasized by the data shown in Table 12. The maximum annual run-off for different streams ranges from 1.96 times the long-time average (Trinity River) to 4.22 times the long-time average (Nueces River). The minimum annual run-off varies from 16.6 percent (Brazos River) to 33.2 percent (Guadalupe River). It was found that the maximum monthly run-off ranges from 61 percent of the long-time average annual run-off (Sabine River) to 254 percent for the Nueces River. The minimum monthly run-off was found to range from zero to one percent for the various streams.

TABLE 12

Run-off 1924-1953 (1000 Acre-Feet) for Selected Streams

	Drainage Area Sq, Mi.	30- Year Average	Maximum Annual Run-off	Minimum Annual Run-off	Maximum Monthly Run-off	Minimum Monthly Run-off
Sabine River Near Ruliff	9440	6655.8	13054.2 (1946) 196.0%	1348.0 (1951) 20.3%	4060.0 (May 1953) 61.0%	23.2 (Oct. 1952) 0.3%
Neches River at Evadale	7908	4833.6	9493.7 (1946) 197.0%	1419.0 (1951) 29.2%	3065.0 (May 1944) 63.5%	11.1 (Aug 1925) 0.2%
Trinity River at Romayor	17192	5596.9	12276.4 (1945) 220.0%	1504.2 (1951) 26.9%	3910.0 (Apr 1945) 70.0%	9.9 (Aug 1925) 0.2%
Brazos River At Richmond	34810	5374.4	13010.5 (1941) 242.0%	891.9 (1951) 16.6%	3309.0 (May 1935) 61.5%	8.7 (Aug 1934) 0.2%
Colorado River at Columbus	29170	2319.3	6138.5 (1936) 265.0%	765.2 (1952) 33.0%	1945.0 (Sep 1936) 84.0%	12.5 (Oct 1934) 0.5%
Guadalupe* River at Victoria	5311	1136.5	2568.7 (1926) 226.0%	377.5 (1951) 33.2%	1133.0 (Jul 1936) 100.0%	11.1 (Aug 1934) 1.0%
Nueces River near Three Rivers	15600	591.7	2492.7 (1935) 422.0%	114.3 (1933) 19.3%	1501.0 Jun 1935) 254.0%	Zero (Numerous 0%

* Based on a separate study for the early years of this record.

Note: Percentages shown are all in terms of the 30-year average run-off.

Run-off in Brazos and Colorado River Basins

When work was started on the assignment of the Texas Water Resources Committee, it was realized that there was neither the time nor the money to permit a detailed study leading to a finished inventory of the water resources of the entire State. In lieu thereof the Brazos and Colorado River Basins were selected for intensive study with the hope that the results obtained from these two basins might be applied to the remainder of the State. In other words, these two basins were to be make the "guinea-pigs" for the rest of the State. The investigations on these two basins were interrupted early in 1955 when funds for technical help were exhausted. Much work on this line has been done since then, however, for the Texas Electric Service Company, the results of which were published in a report entitled, Run-off in the Brazos and Colorado River Basins, March 1955.

Subsequently, another report bearing on this subject was prepared for the Texas Electric Service Company under the title, Preliminary Plan-Brazos River Basin-Comprehensive Development for Water Conservation, January 1956. The results of those investigations have been used freely in the present report through the cooperation of the Texas Electric Service Company.

In addition to the charts showing variations in rainfall, (Figures 5 and 6), which are reproduced from the Brazos River Report, above mentioned, a series of charts showing the variations in run-off has been reproduced from the report on Run-off in the Brazos and Colorado River Basins. The five charts in this series, represented by Figures 18 through 22, reflect the run-off under the following conditions: Run-off for the long-time period, 1924 - 1953, and then, comparative run-off for shorter periods of time.

Each of the two stream basins was divided into sixteen sub-basins for the purpose of this study, as shown on the charts. Because of the variation in size of the sub-basins, a direct comparison of run-off is difficult. In order to overcome this difficulty the run-off from each sub-basin was used in terms of the depth in inches, which gives a common basis for comparison irrespective of the size of the area.

It was found as illustrated by the charts that the lines of equal run-off trend generally north and south, becoming progressively closer together in going from west to east in these two drainage basins. This is true for each of the charts, regardless of the length of record or the period of time covered. The same pattern with local variations would follow for the rest of the State. Just as happens with the rainfall, the lines of equal run-off get closer together as the Louisiana border is approached. And, as the coast line becomes more southerly below the mouth of the Guadalupe River on San Antonio Bay, the lines of equal run-off would tend to parallel the coast.

One item that has had some influence in causing the noticeable difference in depth of run-off between the early and late years of the 30-year study period, as indicated by this series of charts, is the current drought. However, the drought alone is not responsible for the great decrease in run-off. A big part of the reduction in run-off can be attributed to the changes in water use that are taking place on the watersheds. Some of these changes that are known to have been effective within the later years of this period are:

1. Increased evaporation losses from reservoirs and small ponds.
2. Expansion in watershed uses, including the S. C. S. land treatment program.
3. Additional, or higher, municipal uses in the more recent years.

Specific information as to the net effect of the drought and of each of these other items upon the water supply are not available. While the importance of each of them is recognized, with particular reference to planning the future uses of water resources of the State, detailed studies leading to such a determination are far beyond the scope of this report.

Streams in their natural state rarely yield a dependable water supply for more than a fraction of the total run-off that originates within the basin, due to the erratic pattern of the inflow. The only way by which this small natural dependable yield can be increased is through the regulation of the stream flow by reservoir storage. Reservoirs provide regulation for the use by man of stream flow that ordinarily is not otherwise available on a full-time basis. The erratic nature of stream flow in practically all streams of Texas has been pictured by the monthly hydrographs that have been prepared for seven of the major drainage basins (Figures 11 through 17). Information in Table 12 shows that the minimum monthly flow in the natural state for each of these streams has ranged from zero to one percent of the mean annual flow. Through the construction of reservoirs, and the storage of water during periods of flood flow for subsequent use, the dependable yields can thus be greatly increased.

Storage facilities are usually provided to meet specific purposes, all of which are common in that water is impounded while it is surplus for later use after the floods have passed. The more common purposes for which water is impounded by reservoirs are:

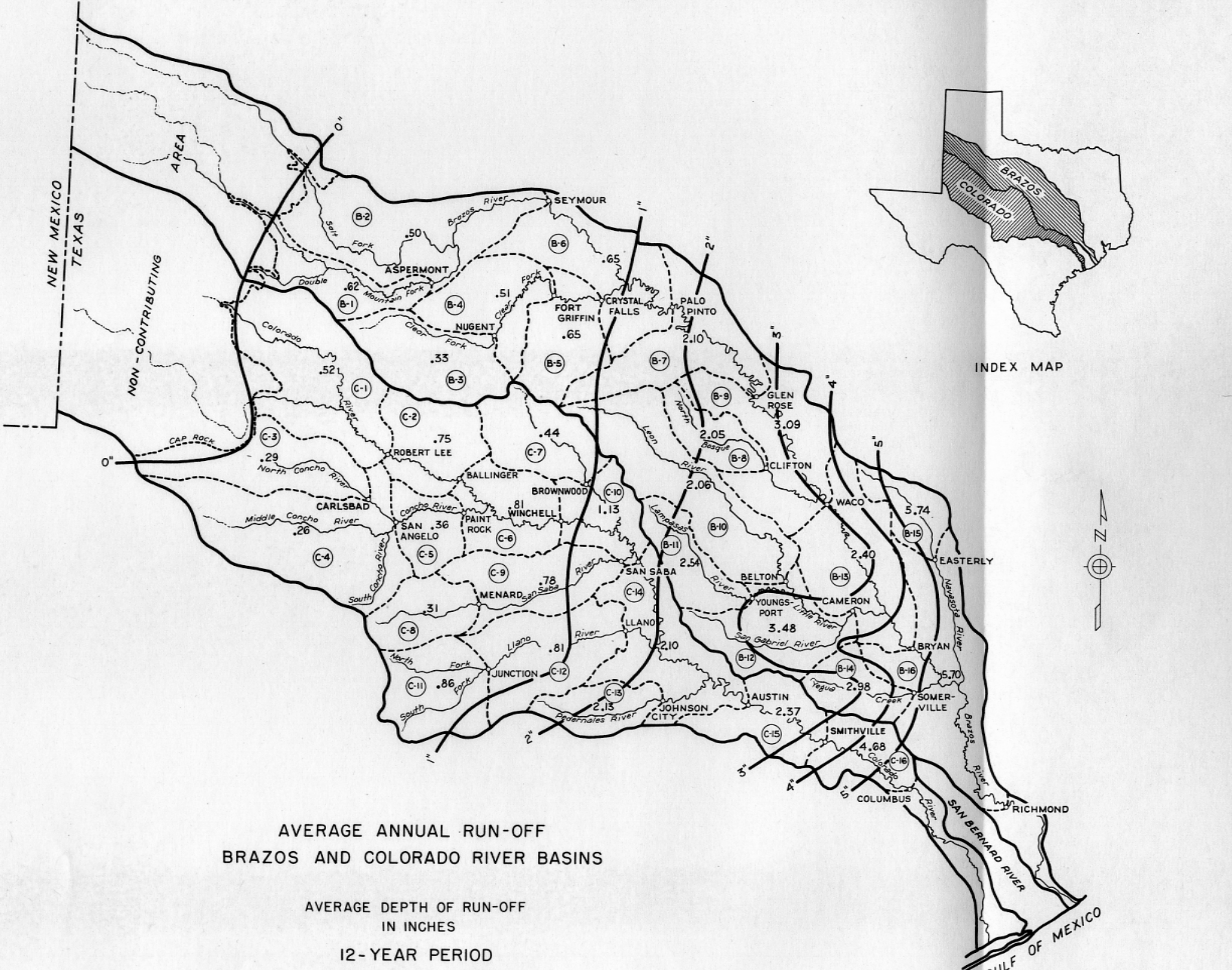
Municipal and Domestic
Irrigation
Industrial
Hydroelectric Power
Navigation
Flood Control
Recreation

Reservoirs in Texas completed or under construction as of September 1, 1956, had a combined total storage capacity of 26,818,410 acre-feet, according to data contained in U.S.G.S. Water Supply Paper 1360-A, Reservoirs in the United States and information on file with the Board of Water Engineers. Pertinent data from this water supply paper and other sources have been summarized herein as Table 13. This table includes reservoirs with a usable capacity in excess of 5,000 acre-feet, as well as those located on interstate and international streams, such as Lake Texoma and Falcon Reservoir.

The reservoirs and their usable storage capacities can be summarized according to use as follows:

Existing Reservoirs

Capacity	Acre-Feet	% of Total Capacity
Conservation	6,827,480	25.5%
Hydroelectric Power	4,945,950	18.4%
Flood Control	12,763,560	47.6%
Dead, Sediment and Power Head	2,281,420	8.5%
Total	26,818,410	100.0%

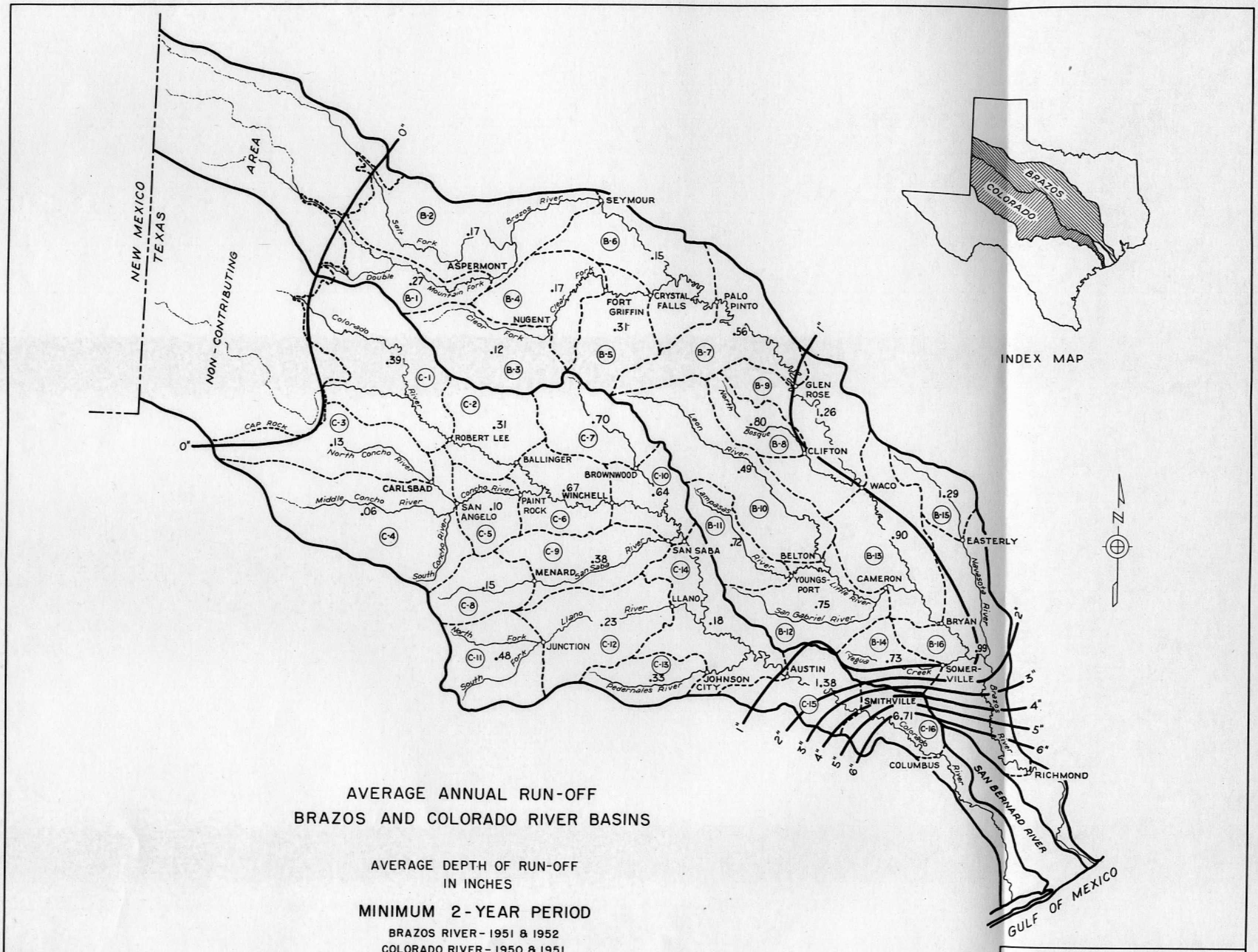


AVERAGE ANNUAL RUN-OFF
BRAZOS AND COLORADO RIVER BASINS

AVERAGE DEPTH OF RUN-OFF
IN INCHES

12-YEAR PERIOD
1942-1953, INCL.

PREPARED IN THE OFFICE OF
ROBERT L. LOWRY, CONSULTING ENGINEER
AUSTIN, TEXAS FEBRUARY 1955



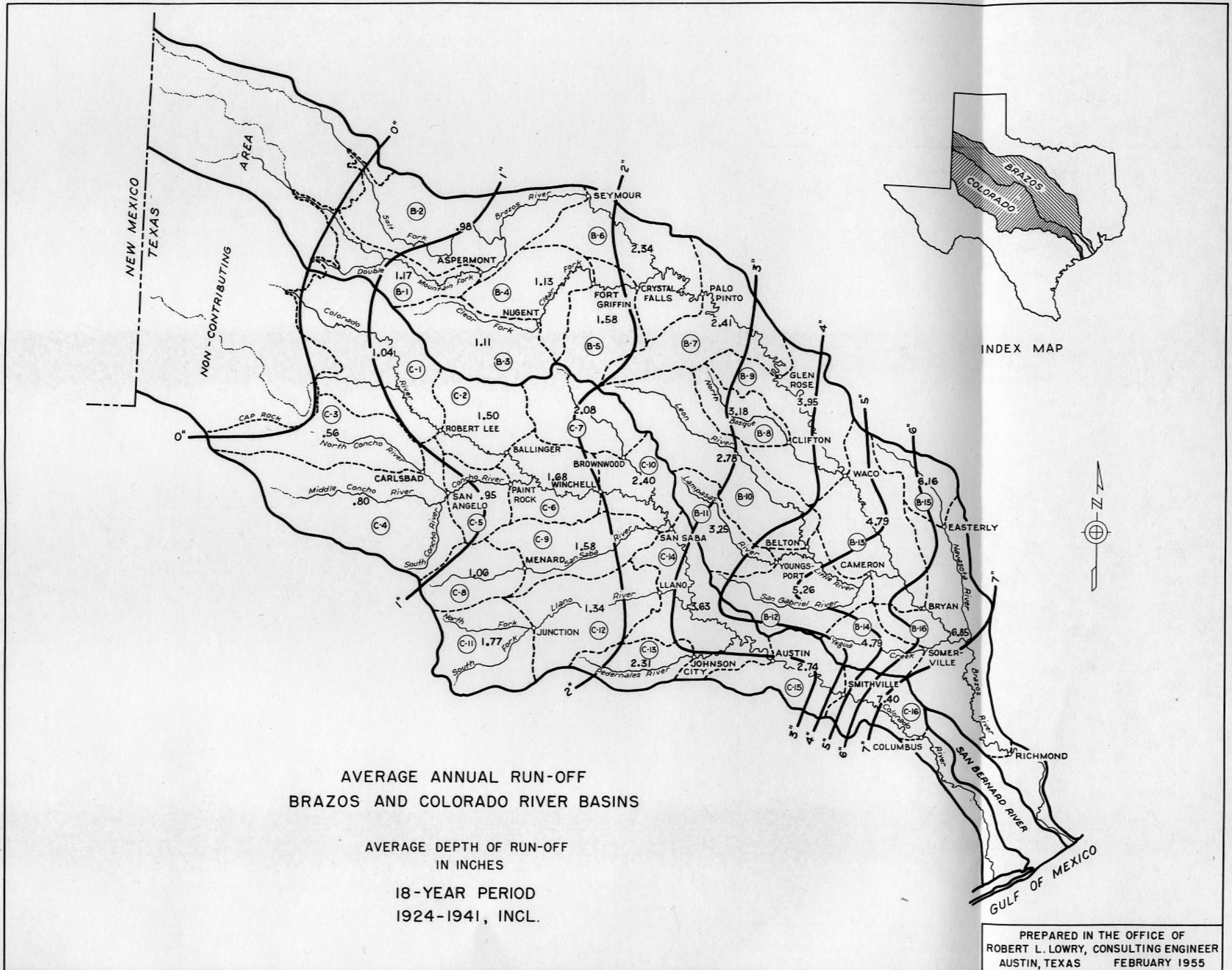
AVERAGE ANNUAL RUN-OFF
BRAZOS AND COLORADO RIVER BASINS

AVERAGE DEPTH OF RUN-OFF
IN INCHES

MINIMUM 2-YEAR PERIOD

BRAZOS RIVER - 1951 & 1952
COLORADO RIVER - 1950 & 1951

PREPARED IN THE OFFICE OF
ROBERT L. LOWRY, CONSULTING ENGINEER
AUSTIN, TEXAS FEBRUARY 1955

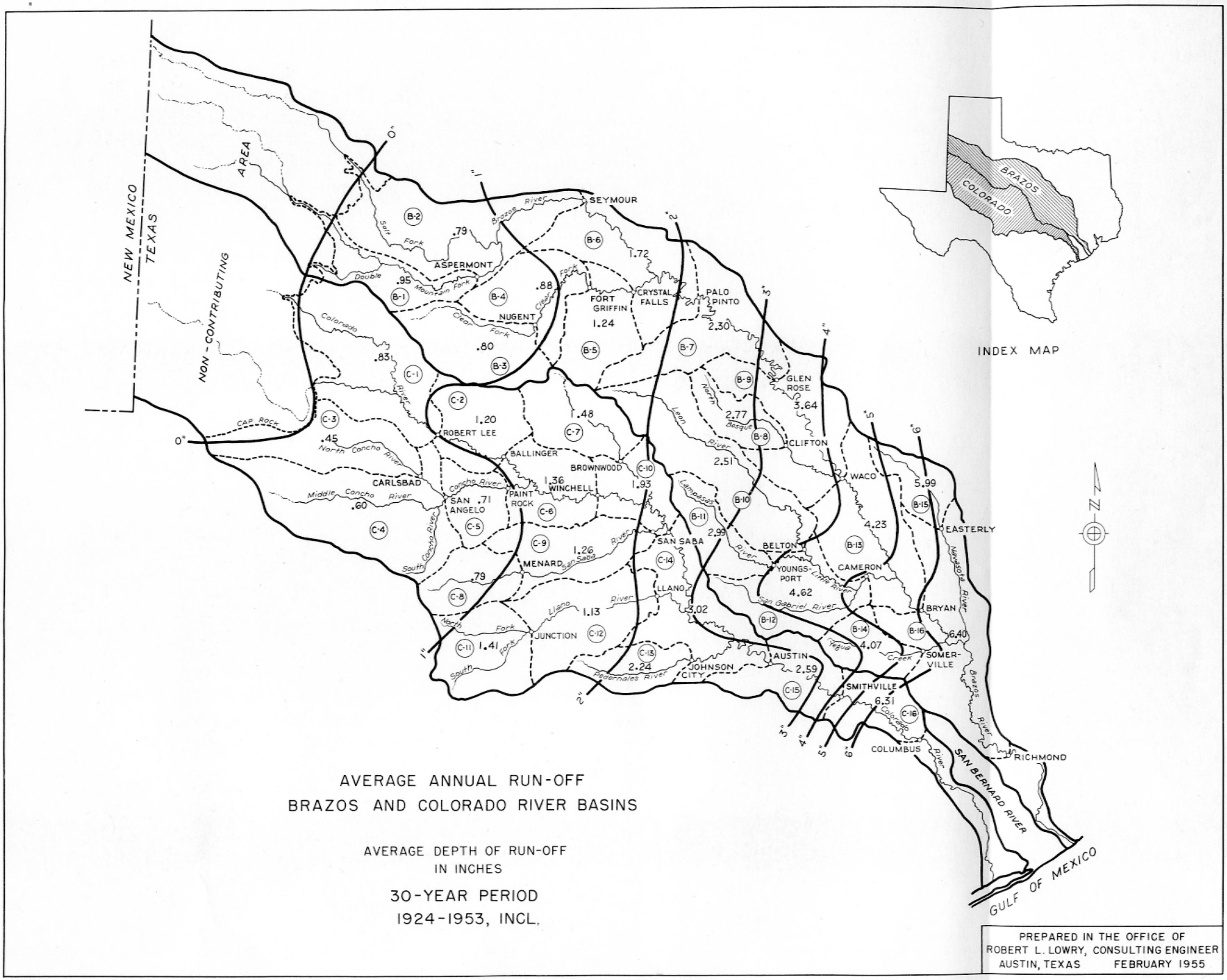


AVERAGE ANNUAL RUN-OFF
BRAZOS AND COLORADO RIVER BASINS

AVERAGE DEPTH OF RUN-OFF
IN INCHES

18-YEAR PERIOD
1924-1941, INCL.

PREPARED IN THE OFFICE OF
ROBERT L. LOWRY, CONSULTING ENGINEER
AUSTIN, TEXAS FEBRUARY 1955



AVERAGE ANNUAL RUN-OFF
BRAZOS AND COLORADO RIVER BASINS

AVERAGE DEPTH OF RUN-OFF
IN INCHES

30-YEAR PERIOD
1924-1953, INCL.

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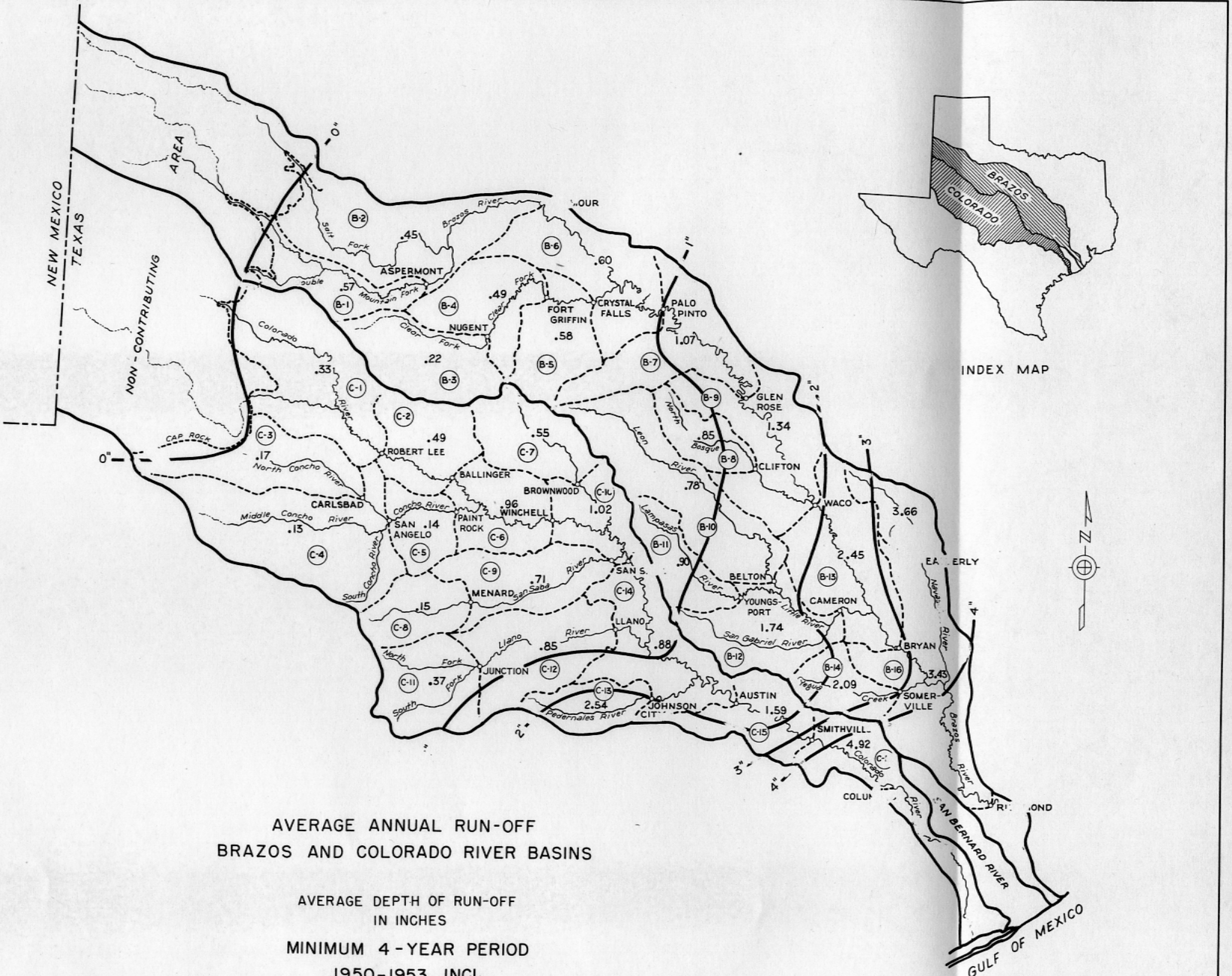
AUSTIN, TEXAS FEBRUARY 1955



AVERAGE ANNUAL RUN-OFF
BRAZOS AND COLORADO RIVER BASINS

AVERAGE DEPTH OF RUN-OFF
IN INCHES

MINIMUM 4-YEAR PERIOD
1950-1953, INCL.

PREPARED IN THE OFFICE OF
ROBERT L. LOWRY, CONSULTING ENGINEER
AUSTIN, TEXAS FEBRUARY 1955

TABLE 13
EXISTING RESERVOIRS IN TEXAS

Reservoir	Stream	Basin	Total Storage	Dead Storage	Conservation Storage	Power Storage	Flood Control Storage	Source
Abbott	Guadalupe River	Guadalupe	5,000	0	0	5,000	0	1
Addicks	South Mayde Cr.	San Jacinto	204,500	0	0	0	204,500	2
Anahuac Lake	Turtle Bayou *	Trinity	35,300	0	35,300	0	0	5
Barker	Buffalo Bayou	San Jacinto	207,000	0	0	0	207,000	2
Baylor Creek	Baylor Creek	Red	9,200	0	9,200	0	0	5
Belton	Leon River	Brazos	1,097,600	84,900	125,700	0	887,000	2
Benbrook	Clear Fork Trinity	Trinity	258,600	15,750	72,500	0	170,350	2
Brazoria	-*	Brazos	21,970	600	21,370	0	0	1
Bridgeport	West Fork Trinity	Trinity	270,300	0	270,300	0	0	1
Brownwood	Pecan Bayou	Colorado	136,600	41,000	95,600	0	0	5
Buchanan	Colorado River	Colorado	992,000	37,000	0	955,000	0	1
Buffalo Lake	Tierra Blanca Creek	Red	18,120	0	18,120	0	0	5
Chacon Creek	Chacon Creek	Guadalupe	5,750	0	5,750	0	0	1
Dam B	Neches River	Neches	124,700	16,600	77,600	0	30,500	5
Devils Lake	Devils River	Rio Grande	9,400	0	0	9,400	0	1
Dunlap	Guadalupe	Guadalupe	5,900	0	0	5,900	0	5
Eagle Mountain	West Fork Trinity	Trinity	182,700	0	182,700	0	0	3
Eagle Nest and Manor L.	Varner Creek	Brazos	18,000	4,000	14,000	0	0	1
Ellis Co.	Waxahachie Creek	Trinity	13,500	0	13,500	0	0	5
Ellison Creek	Ellison Creek	Cypress	24,700	200	24,500	0	0	1
Eastland Reservoir	Leon River	Brazos	28,000	0	28,000	0	0	5
Falcon	Rio Grande	Rio Grande	4,085,000	300,000	2,100,000	0	1,685,000	1
Ferrells Bridge	Cypress Creek	Cypress Creek	842,100	0	254,900	0	587,200	5
Fort Phantom Hill	Elm Creek	Brazos	74,310	450	73,860	0	0	1
Garza-Little Elm	Elm Fork Trinity	Trinity	1,016,200	53,500	436,000	0	526,700	2
Granite Shoals	Colorado River	Colorado	137,000	24,000	0	113,000	0	1
Grapevine	Denton Creek	Trinity	435,500	36,000	161,250	0	238,250	2
H-4	Guadalupe River	Guadalupe	7,500	0	0	7,500	0	1
Highlands (East)	Goose Creek	San Jacinto	5,580	0	5,580	0	0	1
Hords Creek	Hords Creek	Colorado	25,310	2,860	5,780	0	16,670	2
Inks	Colorado River	Colorado	17,000	0	0	17,000	0	1
Lake Abilene	Elm Creek	Brazos	9,780	0	9,780	0	0	1
Lake Austin	Colorado River	Colorado	20,000	0	0	20,000	0	1
Lake Balmorhea	Toyah Creek	Pecos	6,340	0	6,340	0	0	1
Lake Bowie	Big Sandy	Trinity	20,000	0	20,000	0	0	5
Lake Cherokee	Cherokee Bayou	Sabine	62,400	11,700	50,700	0	0	1
Lake Camp Creek	Camp Creek	Brazos	8,400	0	8,400	0	0	5
Lake Cisco	Sandy Creek	Brazos	49,100	8,000	41,100	0	0	5

* Off-Channel Reservoir

Table 13 - continued

Reservoir	Stream	Basin	Total Storage	Dead Storage	Conservation Storage	Power Storage	Flood Control Storage	Source
Lake Colorado City	Morgan Creek	Colorado	30,800	200	30,600	0	0	1
Lake Corpus Christi	Nueces River	Nueces	300,000	0	300,000	0	0	5
Lake Coffee Mills	Coffee Mill Creek	Red	8,000	0	8,000	0	0	5
Lake Corsicana	Elm Creek	Trinity	6,250	0	6,250	0	0	5
Lake Creek	Manos Creek	Brazos	9,500	0	9,500	0	0	5
Lake Crook	Pine Creek	Red	10,750	0	10,750	0	0	1
Lake Daniel	Gonzales Creek	Brazos	10,000	0	10,000	0	0	1
Lake Diversion	Wichita River	Red	40,000	0	40,000	0	0	1
Lake Eddleman	Flint Creek	Brazos	5,920	0	5,920	0	0	5
Lake Graham	Salt Creek	Brazos	39,000	0	39,000	0	0	5
Lake Houston	San Jacinto River	San Jacinto	160,000	8,000	152,000	0	0	1
Lake J. B. Thomas	Colorado River	Colorado	204,000	1,300	202,700	0	0	1
Lake Kemp	Wichita River	Red	438,000	0	438,000	0	0	1
Lake Kickapoo	Little Wichita R.	Red	105,000	0	105,000	0	0	5
Lake Kirby	Cedar Creek	Brazos	7,600	0	7,600	0	0	1
Lake Lytle	Lytle Creek	Brazos	6,500	0	0	6,500	0	1
Lake Mineral Wells	Rock Creek	Brazos	9,030	0	9,030	0	0	5
Lake Nasworthy	South Concho R.	Colorado	12,550	0	12,550	0	0	5
Lake Pauline	Wanderers Creek	Red	5,040	0	5,040	0	0	1
Lake Stamford	Paint Creek	Brazos	60,000	3,400	56,000	0	0	1
Lake Sweetwater	Bitter Creek	Brazos	13,280	0	13,280	0	0	1
Lake Texoma	Red River	Red	5,719,000	1,223,000	0	1,783,000	2,713,000	2
Lake Travis	Colorado River	Colorado	1,950,000	28,000	0	1,144,000	778,000	3
Lake Trinidad	-*	Trinity	6,240	0	6,240	0	0	1
Lake Tyler	Prairie Creek	Neches	43,400	4,400	39,000	0	0	1
Lake Waco	Bosque River	Brazos	22,020	0	22,020	0	0	1
Lake Wichita	Holiday Creek	Red	14,030	3,030	11,000	0	0	1
Lake Worth	West Fork Trinity	Trinity	47,170	7,100	40,070	0	0	1
Lavon	East Fork Trinity	Trinity	423,400	47,800	100,000	0	275,600	2
Lake Gladewater	Glade Creek	Sabine	6,950	0	6,950	0	0	5
Marble Falls	Colorado River	Colorado	24,500	1,250	0	23,250	0	1
Marine Creek	Marine Creek	Trinity	15,370	0	3,780	0	11,590	5
Medina	Medina River	Guadalupe	254,000	4,780	249,220	0	0	3
McClellan Creek	McClellan Creek	Red	5,000	0	5,000	0	0	5
Mountain Creek	Mountain Creek	Trinity	27,100	0	27,100	0	0	1
Monte Alto Reservoir	Rio Grande *	Rio Grande	20,000	0	20,000	0	0	5
Oak Creek	Oak Creek	Colorado	39,200	2,500	36,700	0	0	1

* Off-Channel Reservoir

Table 13 - continued

Reservoir	Stream	Basin	Total Storage	Dead Storage	Conservation Storage	Power Storage	Flood Control Storage	Source
Olmos	San Antonio River	Guadalupe	15,500	0	0	0	15,500	1
Priddy Reservoir	Palo Duro Creek	Red	5,320	0	5,320	0	0	5
Possum Kingdom	Brazos River	Brazos	724,700	0	0	724,700	0	1
Red Bluff	Pecos River	Pecos	270,000	20,000	250,000	0	0	4
Rita Blanca	Rita Blanca Creek	Canadian	12,100	0	12,100	0	0	5
River Crest Reservoir	Sulphur River	Sulphur	7,100	0	7,100	0	0	5
San Angelo	North Concho Riv.	Colorado	391,500	33,900	80,400	0	277,200	2
San Estaban	Alameda Creek	Rio Grande	6,760	0	6,760	0	0	5
Sandow Water Company	Sandy Creek	Brazos	12,000	0	12,000	0	0	1
Sheldon Reservoir	Carpenters Bayou	San Jacinto	6,950	0	6,950	0	0	5
Santa Rosa Lake	Beaver Creek	Red	11,600	0	11,600	0	0	1
Terrell	Muddy-Cedar Creek	Trinity	8,300	0	8,300	0	0	5
Texarkana	Sulphur River	Sulphur	2,654,300	0	145,300	0	2,509,000	2
Tranquitas	Tranquitas	Coastal	6,000	0	6,000	0	0	1
Village Creek	Village Creek	Trinity	45,710	0	45,710	0	0	5
Whitney	Brazos River	Brazos	2,017,500	255,300	0	131,700	1,630,500	2
White Rock Lake	Trinity *	Trinity	14,270	0	14,270	0	0	5
William Harris	Brazos River *	Brazos	12,000	900	11,100	0	0	1
Valley Acres	Rio Grande *	Rio Grande	7,840	0	7,840	0	0	5
	TOTAL		26,818,410	2,281,420	6,827,480	4,945,950	12,763,560	

Key to source of data:

1. U. S. Geological Survey Water Supply Paper 1360-A, Reservoirs in the United States
2. Water Resources Development by Corps of Engineers in Texas, Southwestern Division, Corps of Engineers, January, 1955
3. U. S. Geological Survey Water Supply Paper 1282, Surface Water Supply of the United States, Part 8, 1953
4. Sen. Doc. 109, 81st Congress, 1st Session, Pecos River Compact Documents, page 67
5. Board of Water Engineers files

* Off-Channel Reservoir

** This total is identical to that of a similar tabulation by the Board of Water Engineers with the following exceptions:

1. The full capacities of Falcon Reservoir and Lake Texoma on the boundary streams are included in this table, and
2. Minor differences in sources of information

Additional reservoirs are now planned which will more than double the existing storage capacity and will greatly increase the yield of water that can be made available from Texas streams. Thirty-eight reservoirs having a combined capacity of about 20 million acre-feet are presently proposed by local groups and appropriate Federal agencies for municipal, industrial, and irrigation uses, together with flood control and the development of hydroelectric power. These reservoirs are listed in Table 14.

The proposed reservoirs and their usable storage capacities have been summarized according to use as follows:

Proposed Reservoirs

Capacity	Acre-feet	Percent of Total Proposed Capacity
Conservation	8,697,200	42.6 %
Hydroelectric Power	1,629,800	8.0
Flood Control	6,232,700	30.6
Dead, Sediment, and Power Head	3,829,400	18.8
Total	20,389,100	100.0 %

While many large reservoirs have been built in Texas, and more are proposed, the allocation of storage for conservation purposes (other than for the generation of power) is small. On existing reservoirs about 26 percent of the controlled storage is for conservation, while in those reservoirs now proposed the conservation storage will be approximately 43 percent of the total capacity.

TABLE 14
PROPOSED RESERVOIRS IN TEXAS
Units: Acre-Feet

Reservoir	Stream	Basin	Total Storage	Dead Storage	Conservation Storage	Power Storage	Flood Control Storage	Source
Iron Bridge	Sabine River	Sabine	926,000	0	926,000	0	0	2
McGee Bend	Angelina River	Neches	4,040,800	1,508,400	**	1,383,500	1,148,900	1
12 Reservoirs included in San Jacinto River Authority Plan	-	San Jacinto	730,000	0	730,000	0	0	2
Navarro Mills	Richland Creek	Trinity	203,400	15,100	53,200	0	135,100	1
Richland Creek	Richland Creek	Trinity	1,130,000	0	1,130,000	0	0	2
Possum Kingdom Enlargement	Brazos River	Brazos	273,300*	0	0	193,300	80,000	3
Turkey Creek	Brazos River	Brazos	159,000	91,000	20,000	27,000	21,000	3
Inspiration Point	Brazos River	Brazos	203,000	141,000	26,000	10,000	26,000	3
Hightower	Brazos River	Brazos	520,000	441,000	48,000	0	31,000	3
DeCordova Bend	Brazos River	Brazos	155,000	80,000	28,000	6,000	41,000	3
Bee Mountain	Brazos River	Brazos	360,000	319,000	31,000	10,000	0	3
Lake Waco Enlargement	Bosque River	Brazos	570,100*	0	82,100	0	488,000	1
Ferguson	Navasota River	Brazos	619,200	40,600	62,200	0	516,400	1
Laneport	San Gabriel River	Brazos	281,100	16,600	28,400	0	236,100	1
Lampasas	Lampasas River	Brazos	481,000	34,900	56,200	0	389,900	1
Somerville	Yegua Creek	Brazos	390,700	25,900	38,800	0	326,000	1
Proctor ***	Leon River	Brazos	320,700	32,700	31,400	0	256,600	1
Stryker Creek	Stryker Creek	Neches	26,500	0	26,500	0	0	1
Mud Creek	Muc Creek	Neches	44,000	0	44,000	0	0	2
Gum Creek	Gum Creek	Neches	30,500	0	30,500	0	0	2
Lake Brownwood Enlargement	Pecan Bayou	Colorado	279,700*	0	279,700	0	0	2
Canyon	Guadalupe River	Guadalupe	741,000	28,100	366,400	0	346,500	1
Gonzales	San Marcos River	Guadalupe	539,000	25,000	100,800	0	413,200	1
Sanford	Canadian River	Canadian	961,600	461,600	500,000	0	0	2
Diablo ****	Rio Grande	Rio Grande	5,977,000	550,000	3,650,000	0	1,777,000	4
Smithers Lake	*	Brazos	16,500	0	16,500	0	0	2
Blackburn Crossing	Neches	Neches	410,000	18,500	391,500	0	0	2
TOTAL			20,389,100	3,829,400	8,697,200	1,629,800	6,232,700	

* In addition to existing capacity
** Some included in power storage capacity. Detailed breakdown not available
*** Will make additional conservation capacity available in Belton Reservoir by transfer of flood control storage upstream
**** Preliminary and tentative

Key to source material: (Table 14)

1. Water Resource Development by Corps of Engineers in Texas

2. Permits, Presentations, and Reports on file with Board of Water Engineers

3. Plan of Development, Brazos River Authority

4. International Boundary and Water Commission

CONCLUSIONS

Certain conclusions with respect to run-off in Texas are clear and unmistakable. They can be enumerated as follows:

1. Texas is not a homogeneous unit in so far as run-off is concerned.

   a. All of the run-off in Texas comes from 85 percent of the total land area.

   b. Approximately 99 percent of the run-off comes from the two geographic provinces, the Gulf Coastal Plain and Central Texas, that together comprise about 75 percent of the total land area.

   c. 75 percent of all of the run-off comes from the northern half of the Gulf Coastal Plain (from the Brazos River east and north to the state border) plus a small area in the Central Texas Province (including the Trinity River above Dallas and Little River above Cameron), all of which together comprise about 25 percent of the total land area.

      (1) Actually, the rate of run-off varies within this 25 percent of the area from 3 inches on the west side to more than 15 inches on the east side.

   d. The Geographic Provinces of Texas contribute toward the total run-off as follows:

(1)	Gulf Coastal Plain	78.6 %
(2)	Central Texas Province	20.2 %
(3)	Trans-Pecos Texas	1.2 %
(4)	The High Plains	0
		100.0 %

2. The 15-year average annual run-off from Texas, 1940-1954, has been 44,150,000 acre-feet. This includes only the Texas share of the border streams.

   a. The average annual for 1940-1946 was 59,344,000 acre-feet

   b. The average annual for 1947-1954 was 30,854,000 acre-feet

   c. Minimum 4-year period, 1951-1954 averaged 22,664,000 acre-feet annually.

      (1) This is the most significant figure among those given above. A large proportion of this total is made up of unregulated flood flows, which are not usable under present conditions, and only a part thereof could be economically impounded.

   d. By creating adequate additional storage it is possible that 2/3 of the total of 22,664,000 acre-feet or 15,000,000 acre-feet might be made usable.

3. Run-off from Texas directly into the Gulf has averaged 34,354,800 acre-feet per year since 1940.

   a. The Sabine, Neches, Trinity and Brazos rivers have contributed 68.8 percent of the total run-off into the Gulf, made up as follows:

	15-Year Average Annual Run-off 1000 Acre-Feet
Sabine (Texas portion) River	5,534.5
Neches River	6,095.7
Trinity River	6,362.3
Brazos River	5,657.7
	23,650.2

   b. During the last four years, 1951-1954, the average run-off into the Gulf was 18,115,000 acre-feet.

      (1) In 1954 the total inflow into the Gulf was only 10,263,000 acre-feet.

4. An average of about 10,000,000 acre-feet per year flows from Texas into Oklahoma, Arkansas, and Louisiana.

   a. Only about 1,000,000 acre-feet per year enters the State from New Mexico.

   b. One-half of all water leaving Texas to enter the adjacent states is through the Red River.

5. Annual run-off from Texas streams is not at a constant rate, although a number of streams are partially regulated for power releases.

   a. Minimum annual run-off from major drainage areas may vary from 16 to 33 percent of the long-time average run-off.

   b. Maximum annual run-off from these same streams will range from about 2 to 4.2 times the long-time average run-off.

6. Monthly run-off from Texas streams is more erratic than annual run-off.

   a. Minimum monthly run-off varies from zero to about 1.0 percent of the average annual run-off.

   b. Maximum monthly run-off ranges from 61 percent to 254 percent of the average annual run-off.

In addition to the conclusions enumerated above the following discussion more fully brings out the facts that have been separately developed in various parts of the text.

Texas, although a political unit among the states, is not a homogeneous area with respect to geography or to climate. It has also been shown that it cannot be considered as a unit with respect to run-off. Four geographic provinces are represented in Texas, but only two of these, which together comprise about 75 percent of the area, furnish any appreciable run-off.

Most of the run-off comes from less than half of the area of these two provinces. Climatic variations in Texas range from semi-tropical to almost polar, and from himid to distinctly arid. It is obvious, therefore, that averages over Texas are wholly meaningless, whether in connection with rainfall or run-off. Because of the great disparity in run-off from one part of the State to another, any reference to run-off must be related to location in the State.

The topography of the State bears some direct relation to the distribution of run-off, and very definitely controls the location of dam and reservoir sites within the State. As an example, most of the run-off in Texas originates on the eastern part of the Gulf Coastal Plain, which is all low in elevation and does not provide the most advantageous damsites. The remainder of the Coastal Plain, which is also low in elevation, produces only a minor run-off. The area of the State west of the Pecos River and on the High Plains comprises the highest part of Texas with respect to elevation, but it contributes the lowest rates of run-off. Proximity to the Gulf is not the answer, because the part of the Coastal Plain south and west of the Brazos is just as near the coast as the area in East Texas, yet this southwestern area along the coast contributes only a small fraction of the run-off. The major factor in the location of run-off is obviously the rainfall pattern, which is distinct and well established.

The attached map as shown on Figure 23 shows Texas divided into zones of run-off. There are only four belts shown, which cover the range from zero run-off to the highest run-off in the State. Between these two belts there have been placed two intermediate belts labelled West Intermediate Zone with slight run-off and East Intermediate Zone with moderate run-off, each of which could best be described as a fringe area in relation to the adjacent extremes.

For instance, about three-quarters of all the run-off in Texas originates in the block outlined in East Texas. Practically no run-off (only 1.2%) comes from the West Texas area. The fringe area along the west side of the East Texas block is more closely related to the area of heavy run-off, although it furnishes run-off at only a fraction of the rate that is sustained within the block to the east.

The intermediate zone which adjoins the Western belt and which is shown to extend from the mouth of the Rio Grande to the northern tip of the Panhandle, is closely associated with the zone of no run-off. Along the western boundary of this zone (where it joins the High Plains, the Trans-Pecos Texas, and thence parallels the Rio Grande to the coast) the run-off is practically zero. Run-off increases generally toward the east, but throughout this zone it is relatively low.

This distribution of run-off in Texas is highly significant with respect to any plans for the future development of the water supply. In this connection it should be amply clear that there are only certain areas in the State in which there are any large amounts of run-off available for development. First, all of the western area, including Trans-Pecos Texas and the High Plains, furnishes no run-off to stream flow outside of its immediate boundaries. Therefore, whatever local development is made of the run-off in those areas can have no effect on the remainder of the State. Conversely, whatever development and use is made of the run-off that originates in the extreme eastern part of the State, will have no influence on the water problems of the areas West of the Pecos or on the High Plains. The run-off that takes place from the two intermediate zones presents more of a problem. In the western part of this zone the very meagerness of the run-off presents a problem. Throughout most of the area there is a real and definite deficiency of run-off, and only by making use within the boundaries of this area of the small supply that is available, can there be any expansion in the present development. Run-off in the eastern intermediate zone begins to increase, thus presenting possibilities for further development that do not exist west of this area. The run-off that originates within this area, however, is not sufficiently great to permit of large expansion in uses even in this area. In East Texas there are still large volumes of run-off as yet unused. The best opportunity for any great expansion of water uses in Texas is more-or-less limited to the water supply of this one area. In other words, the continued increase in water use in Texas from the surface water supply will of necessity have to be from the eastern part of the state because that is where the only major run-off occurs.

This may be said another way by referring to the map showing average annual rainfall for Texas (Figure 4). The important run-off producing area of the State lies wholly east of the line of 30 inches of rainfall. West of this line there is a definite deficiency of run-off.

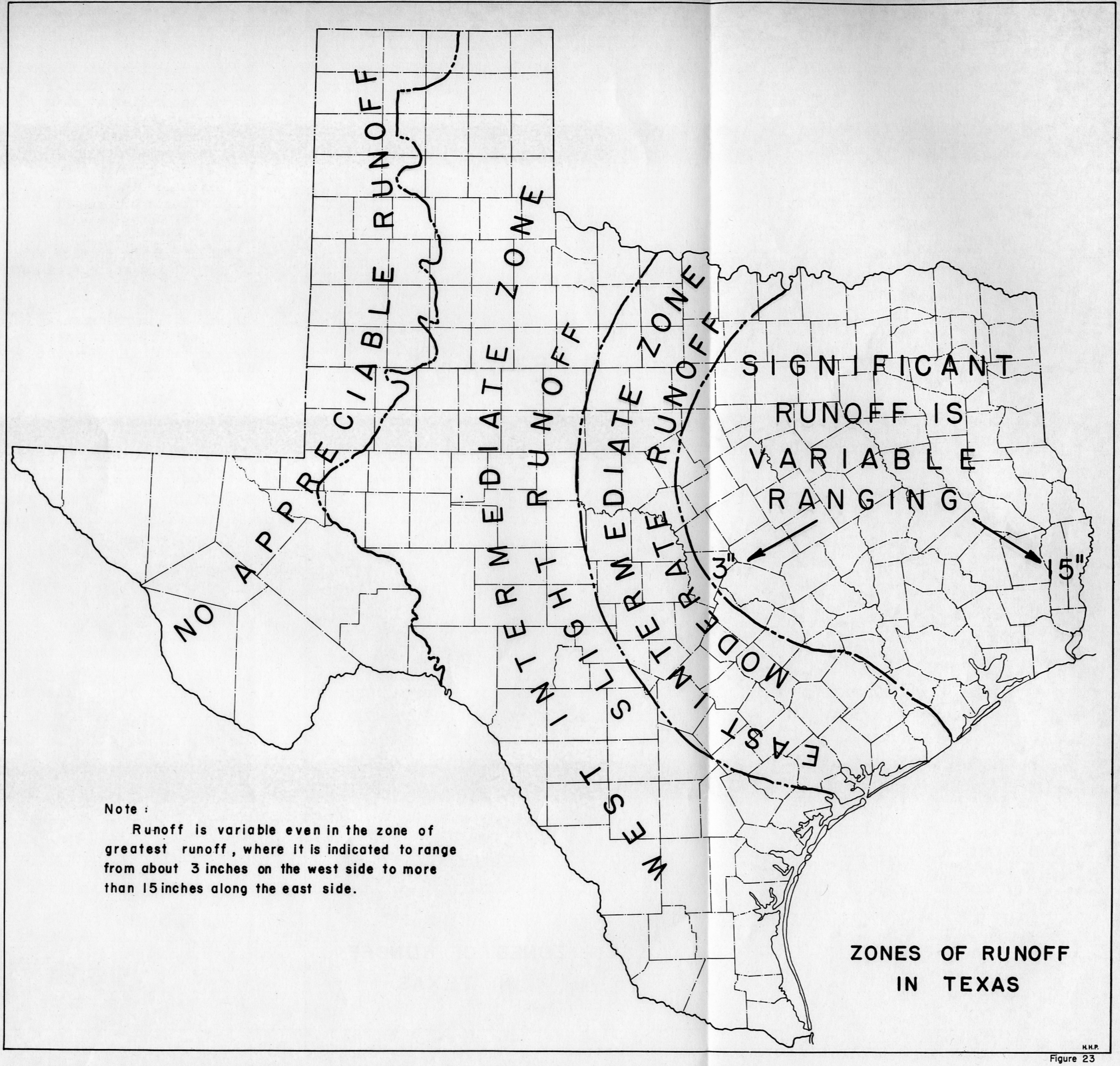

NO APPRECIABLE RUNOFF
INTERMEDIATE ZONE
SLIGHT RUNOFF
WEST INTERMEDIATE ZONE
MODERATE RUNOFF
EAST
SIGNIFICANT
RUNOFF IS
VARIABLE
RANGING
3"
15"
Note :
Runoff is variable even in the zone of greatest runoff, where it is indicated to range from about 3 inches on the west side to more than 15 inches along the east side.
ZONES OF RUNOFF
IN TEXAS
H.H.P.

Figure 23