TEXAS WATER DEVELOPMENT BOARD

REPORT 6

HYDROLOGIC STUDIES OF SMALL WATERSHEDS
MUKEWATER CREEK, COLORADO RIVER BASIN
TEXAS, 1952-60

By

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Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
and the
U.S. Soil Conservation Service

November 1965

Published and distributed
by the
Texas Water Development Board
Post Office Box 12386
Austin, Texas 78711

FOREWORD

On September 1, 1965 the Texas Water Commission (formerly, before February 1962, the State Board of Water Engineers) experienced a far-reaching realignment of functions and personnel, directed toward the increased emphasis needed for planning and developing Texas' water resources and for administering water rights.

Realigned and concentrated in the Texas Water Development Board were the investigative, planning, development, research, financing, and supporting functions, including the reports review and publication functions. The name Texas Water Commission was changed to Texas Water Rights Commission, and responsibility for functions relating to water-rights administration was vested therein.

For the reader's convenience, references in this report have been altered, where necessary, to reflect the current (post September 1, 1965) assignment of responsibility for the function mentioned. In other words credit for a function performed by the Texas Water Commission before the September 1, 1965 realignment generally will be given in this report either to the Water Development Board or to the Water Rights Commission, depending on which agency now has responsibility for that function.

Texas Water Development Board

John J. Vandertulip

John J. Vandertulip
Chief Engineer

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLES

ILLUSTRATIONS

Figures

TABLE OF CONTENTS (Cont'd.)

HYDROLOGIC STUDIES OF SMALL WATERSHEDS MUKEWATER CREEK, COLORADO RIVER BASIN TEXAS, 1952-60

ABSTRACT

This report presents data and analyses of hydrologic investigations made on a 70.0-square-mile small watershed study area prior to watershed development. Average annual rainfall for this area is about 26.5 inches. During the period of investigation, weighted-mean annual rainfall was 22.05 inches and average annual runoff was 2.77 inches.

Rain-gage density analyses indicate that the number of rain gages in the watershed could be reduced by about one-half and the computed average rainfall would, for one standard deviation confidence limits, be within ±3 percent of the average computed by using all 19 rain gages. Analyses show that larger reductions yield larger standard errors.

The derived flood-frequency curve for the watershed indicates slightly higher peak values than a corresponding curve based on a regional flood-frequency analysis. The mean annual flood for the stream-gaging station on Mukewater Creek at Trickham was computed to be 2,200 cfs (cubic feet per second), which compares with 1,650 cfs from the regional analysis.

A unit hydrograph analysis did not yield a reliable unit hydrograph for use in this watershed.

Using the rainfall-runoff relation developed for this study, total runoff for the 7 water years 1954-60 was estimated within 2 percent of that gaged; however, individual storm runoff generally could be estimated only within ±15 percent. Consideration of the areal distribution of rainfall did not improve the results.

HYDROLOGIC STUDIES OF SMALL WATERSHEDS
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INTRODUCTION

Interest has been expressed by numerous water resources planning agencies concerning the effect of floodwater-retarding structures on the quantity and mode of occurrence of surface-water runoff downstream from developed watersheds. Also, hydrologists recognize the opportunity afforded by these developments to obtain hydrologic data from small watersheds, as the lack of these data is presently critical in the overall hydrologic picture.

History and Objectives of the Statewide Small Watershed Project

The U.S. Soil Conservation Service is actively engaged in the installation of flood and soil erosion reducing measures in Texas under the authority of "The Flood Control Acts of 1936 and 1944" and "Watershed Protection and Flood Prevention Act" (Public Law 566), as amended.

Part of the plan of the U.S. Soil Conservation Service for the reduction of floods and soil erosion in a watershed is the construction of a series of upstream floodwater-retarding structures. The structures are designed to release floodwater at a rate that will not normally exceed the downstream channel capacity immediately below the structures.

As a result of the Flood Control Act of 1936 and subsequent legislation, the Soil Conservation Service of the U.S. Department of Agriculture is investigating a large part of Texas. Each area investigated is subdivided into small watersheds usually consisting of one creek large enough to cause damaging floods and its tributaries. This creek is then investigated as to feasible methods to use to accomplish the objectives of the legislation. Many of the watersheds investigated require the building of floodwater-retarding structures. The function of a floodwater-retarding structure (Figure 1) is to help control floodflows from a small part of a watershed.

As of September 30, 1963, approximately 763 floodwater-retarding structures had been built in Texas. These partly control flow from an area of about 3,170 square miles. According to reports of the U.S. Study Commission-Texas (1962) and the U.S. Soil Conservation Service (1963), a total of 3,438 sites have been found physically and economically feasible for installation of structures in Texas. Only about 22 percent of feasible structures had been built at the end of the water year 1963.

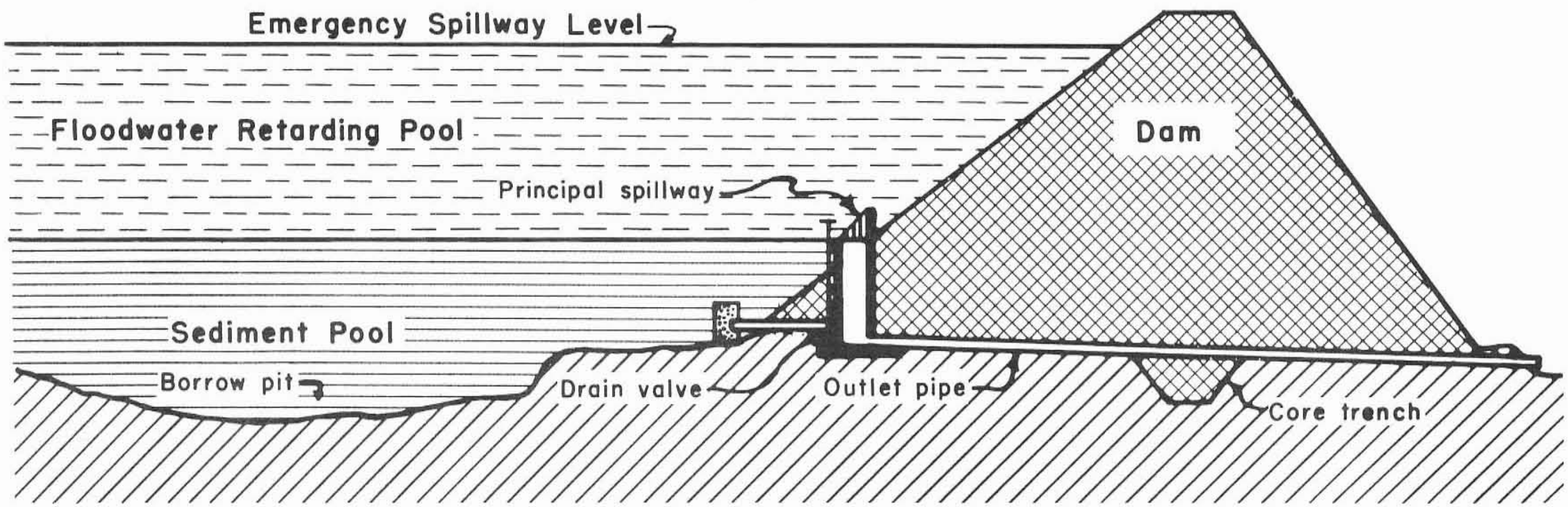


Figure 1

Section of Typical Floodwater-Retarding Structure with Outlet Works

U. S. Geological Survey in cooperation with the Texas Water Development Board
and the U.S. Soil Conservation Service

This watershed-development program will have varying but important effects on the natural surface- and ground-water resources of river basins, especially where a large number of the floodwater-retarding structures are built. Therefore, a need exists for basic hydrologic data of small watersheds that may be used to compare the hydrology under natural conditions with the hydrology under developed conditions after the floodwater-retarding structures are built. Specifically, hydrologic studies are essential to determine the extent to which floodwater-retarding structures affect the yield and mode of occurrence of natural water supplies.

Hydrologic investigations of small watersheds were started in Texas in 1951, and are now being made on 11 areas in the State to provide needed data and analyses (Figure 2). The U.S. Soil Conservation Service, Texas Water Development Board, San Antonio River Authority, city of Dallas, and the Tarrant County Water Control and Improvement District No. 1 are cooperating with the U.S. Geological Survey in these investigations. The 11 study areas were chosen on a statewide basis to sample watersheds having different conditions of rainfall, topography, geology, and soils. On four of the study areas, streamflow and rainfall records are being collected prior to construction of the floodwater-retarding structures, thus affording the opportunity for analyses of the conditions "before and after" development. A summary of the development of floodwater-retarding structures on each study area as of September 30, 1962, is shown in Table 1.

The broad purpose of the statewide investigations is to collect sufficient data to make as many hydrologic interpretations as possible.

Specific objectives to which these studies are directed are:

1. To obtain the basic hydrologic data on small watersheds needed to satisfy the broad purpose.

2. To obtain basic data which will aid in determining the net effect of floodwater-retarding structures on the regimen of streamflow at downstream points.

3. To determine the effect of the impoundments on the underlying ground-water reservoir.

4. To determine the effect of the structures on the sediment yield of the watershed and to determine the trap efficiency of the reservoirs.

5. To develop computation techniques that will give more accurate estimates of runoff resulting from a given amount of rainfall on small watersheds.

6. To develop relationships between maximum rates of runoff and rainfall in small watersheds that will enable more accurate design of small storm-drainage structures.

7. To check the applicability of flood-routing procedures and techniques for small watersheds.

8. To determine the minimum instrumentation necessary for making reliable estimates of total storm inflow to the structures.

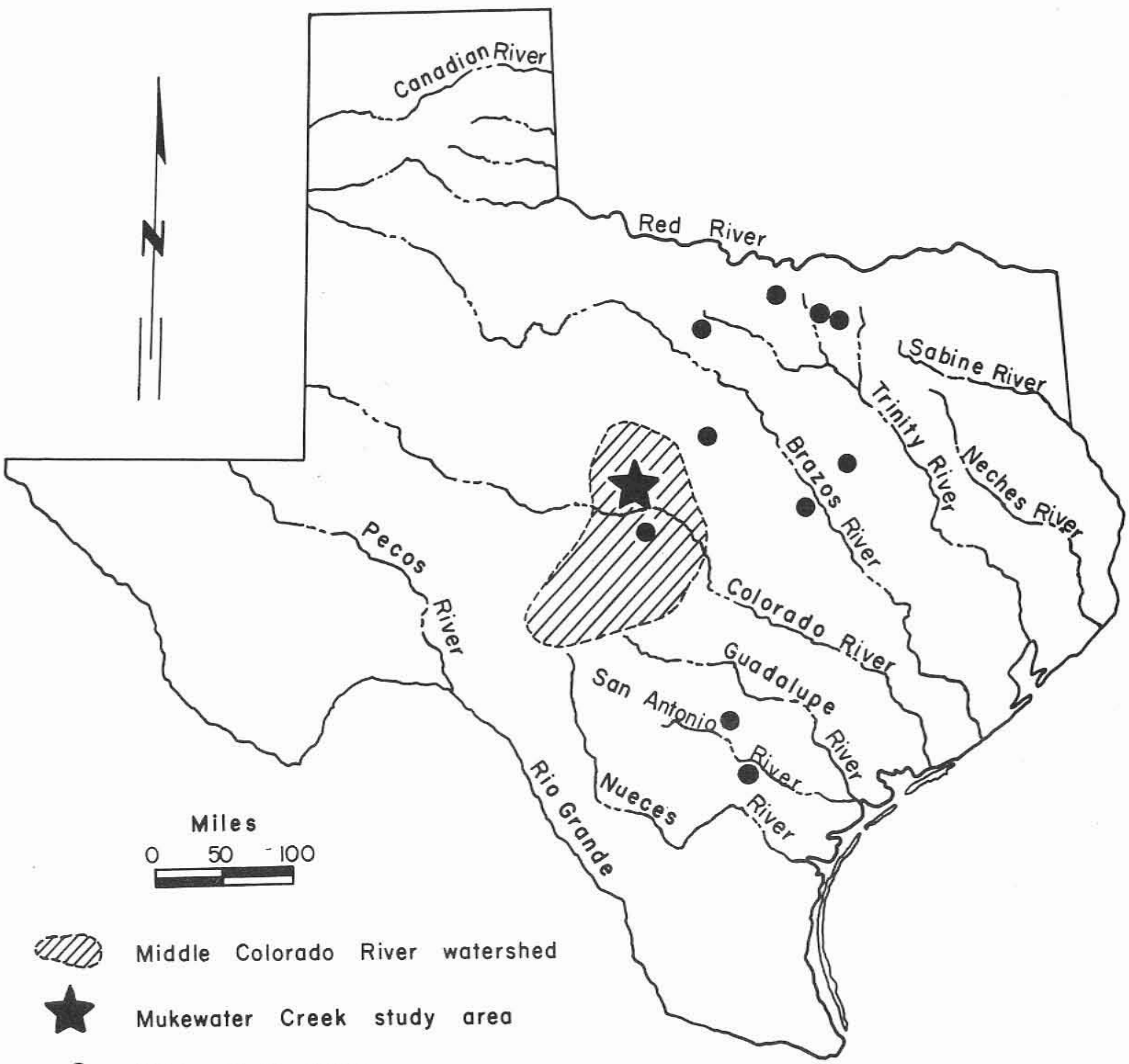


Figure 2

Map of Texas Showing the Location of Mukewater Creek and Other Study Areas

U. S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Table 1.--Small watershed study areas in Texas as of September 30, 1962

Watershed	Drainage area above stream-gaging station (sq mi)	Date hydrologic data collection began	Floodwater-retarding structures above stream-gaging station	Period the structures were built
Trinity River Basin				
North Creek near Jacksboro	21.6	Aug. 1956	None	--
Elm Fork Trinity River near Muenster	46.0	July 1956	11	1954-57
Little Elm Creek near Aubrey	75.5	June 1956	None	--
Honey Creek near McKinney	39.0	July 1951	12	1951-57
Pin Oak Creek near Hubbard	17.6	Sept.1956	None	--
Brazos River Basin				
Green Creek near Alexander	45.5	Oct. 1954	8	1954-56
Cow Bayou near Mooreville	79.6	Sept.1954	9	1955-58
Colorado River Basin				
Deep Creek near Mercury	43.9*	June 1951	6	1951-53
Mukewater Creek near Trickham	70.0	Aug. 1951	5	1961
San Antonio River Basin				
Calaveras Creek near Elmendorf	77.2	Aug. 1954	9	1954-58
Escondido Creek at Kenedy	82.2†	July 1954	10	1954-58

* 8.31 sq mi above Dry Prong Deep Creek near Mercury not included.
† 8.43 sq mi above Escondido Creek subwatershed No. 11 (Dry Escondido Creek) near Kenedy not included.

9. To determine the quality of the water as to its suitability for possible uses and its flocculating characteristics as they affect the sediment-trap efficiency of the pools.

To provide adequate hydrologic sampling, periodic evaluation reports on the hydrology of each study area are essential to insure that the program of basic-data collection is sufficient to meet the purposes of the statewide investigation. This report is one of the periodic evaluations.

One or more interpretive reports will be published covering the investigations on each of the 11 regional small watershed study areas. This series of reports will provide data and interpretations in addition to data available in the U.S. Geological Survey annual Water-Supply Papers.

Thus far, three study area reports have been prepared: "Hydrologic Studies of Small Watersheds, Honey Creek Basin, Collin and Grayson Counties, Texas, 1953-59"; "Hydrologic Studies of Small Watersheds, Deep Creek, Colorado River Basin, Texas, 1951-61"; and "Hydrologic Studies of Small Watersheds, Elm Fork Trinity River Basin, Montague and Cooke Counties, Texas, 1956-60." These three reports cover hydrologic investigations in study areas on which floodwater-retarding structures were constructed prior to or near the beginning of the data-collection program.

In addition to the 11 small watershed study areas mentioned above, which are located in rural areas, the U.S. Geological Survey is collecting data from small urban watersheds: Waller Creek at Austin, and White Rock and Turtle Creeks at Dallas. A report on Waller Creek is in preparation.

Purpose and Scope of This Report

The purpose of this report is to present results of hydrologic investigations conducted in the Mukewater Creek study area during the period 1952-60, prior to the building of floodwater-retarding structures, along with analyses relative to the following objectives:

1. To obtain basic hydrologic data on small watersheds.

2. To obtain basic data which will aid in determining the net effect of proposed floodwater-retarding structures on the regimen of streamflow at downstream points.

3. To develop computation techniques that will give more accurate estimates of runoff resulting from a given amount of rainfall on small watersheds.

4. To determine the minimum instrumentation necessary for making reliable estimates of total stream inflow to the proposed structures.

This report concerns only the period of record prior to the construction of floodwater-retarding structures. The Soil Conservation Service, U.S. Department of Agriculture, began the construction of a system of seven floodwater-retarding structures on the Mukewater Creek watershed in 1961. Land-treatment measures were practiced throughout the report period.

Hydrologic equipment will be installed and the investigations expanded to evaluate the effects of floodwater-retarding structures on the watershed hydrology. A second interpretive report will be released when sufficient data are available after the floodwater-retarding structures are built.

Acknowledgments

The author is indebted to many in the field of hydrology who have contributed written reports on similar investigations, and particularly to his supervisors and to Drs. Walter L. Moore and Carl W. Morgan of The University of Texas for their help, guidance, and encouragement in this investigation.

Portions of this report were used as part of a Master's Thesis submitted by the author, May 1963, to the Graduate School of The University of Texas.

WATERSHED FEATURES

Location and Physiography

The headwaters of Mukewater Creek are near the towns of Santa Anna, in Coleman County, and Bangs, in Brown County (Figure 3). The stream flows in a southeasterly direction through Coleman County for a distance of approximately 30 stream miles, emptying into Home Creek approximately 2½ miles above where it enters the Colorado River. This report is concerned with only the Mukewater Creek study area, which is that 70-square-mile portion of the watershed located above the stream-gaging station, Mukewater Creek at Trickham.

The topography is mildly rolling in the lower and eastern part to steeply rolling along the western edge and in the northwestern part. Divides within the watershed are well defined. The flood plain of the main channel is wide and relatively flat. The steepest part of the area is in the northwest corner. In this area two flat-topped buttes, with very steep side slopes, rise approximately 300 feet above the rolling plains. These two buttes are known locally as the Santa Anna Mountains and, according to local legend, served as lookout points for Indians.

Although some upland parts of the study area are relatively flat, a reconnaissance of the area October 13-14, 1962, following a rainstorm, indicated that all areas contributed to the runoff. Some ponding was noted, particularly in fields which were terraced. Although these terraced areas drain rather slowly, they are considered as contributing to the runoff.

Stream gradients in the study area are rather low, ranging from 0.0018 ft/ft in the lower part of the watershed to 0.0090 ft/ft near the headwaters. The weighted-mean slope of the study area was computed using a method patterned after Carter (1961). Carter computes weighted slope by use of the formula

$$S = \left[\frac{\sum L_i}{\sum (L_i / \sqrt{S_i})} \right]^2 \qquad (1)$$

where S is weighted-mean slope,
L_i is length of stream channel, and
S_i is slope of stream channel.

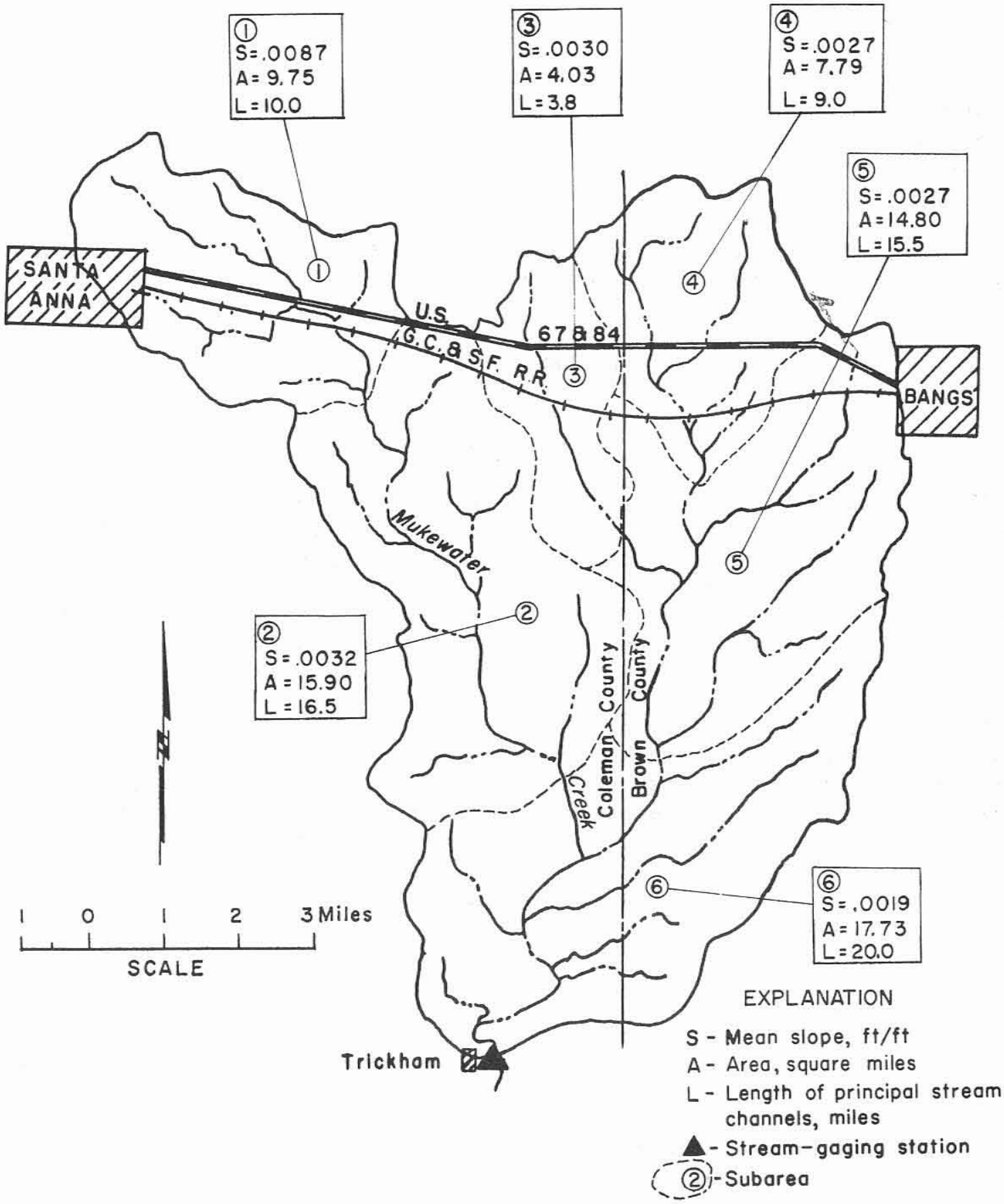


Figure 3

Map of Mukewater Creek Study Area Showing Six Subareas Used for Determining Weighted — Mean Slope

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Channel lengths and slopes were determined only for well-defined channels. S and L and the drainage area for each of the six subareas used for computing weighted-mean slope are shown on Figure 3. Using formula (1), the weighted-mean slope of the study area was found to be 0.0029 ft/ft. Stream gradients were based on elevations determined by altimeter. An altimeter survey of stream channels in the watershed was made by the author on October 13-14, 1962. Point elevations determined are shown on Figure 4. Stream gradients are low but in general increase very rapidly near the rim of the watershed.

Another hydrologic characteristic of a watershed is the mean distance of travel of runoff within the watershed, often referred to as L_{ca}. This characteristic is used as a measure of shape of the drainage area and was found to be 9.1 miles using the grid method as outlined by Benson and Busby (1960).

Rocks of Pennsylvanian age form the surface of the study area except in a small area about 1 mile east of Santa Anna where Cretaceous rocks are exposed in the two steep-sided flat-topped buttes. The Pennsylvanian rocks dip westward, and consist principally of shale and limestone with some interbedded sandstone and conglomerate. The Cretaceous rocks rest unconformably on the eroded surface of Pennsylvanian rocks, and consist of a basal sand capped by a hard crystalline limestone.

Trees in the study area are generally sparse, except along stream channels where shrubs, grass, and trees are more dense. Constrictions in the channel often become clogged with logs and debris during flood periods. The area north of U.S. Highway 67 has a denser growth of trees than the remainder of the area. This area also has a smaller percentage of land in cultivation. Photographs on Figure 5 illustrate the main channel characteristics of Mukewater Creek.

The study area is entirely rural. Small towns near the headwaters do not affect the runoff characteristics of the study area. Farmland treatment and stock ponds comprise the major man-made features that affect the runoff characteristics of the watershed. According to data furnished by the U.S. Soil Conservation Service, there were 211 stock ponds in the study area with a total capacity of 709 acre-feet and a total drainage area of 14.0 square miles in March 1962. Figure 6 shows the locations of the stock ponds. Approximately 45 percent of the study area is in cultivation, 55 percent is in pasture and rangeland, and less than half of 1 percent is in roads and towns. Cultivated land is predominant in the valleys near the stream channels, and the drainage divides are used primarily for pasture and rangeland.

Climate

The climate of the study area is temperate and subhumid. Moderate winters with sudden large changes in temperature are common, as are long summers and comparatively low humidity. The average minimum temperature for January is about 34°F, and the average maximum temperature for August is about 96°F. Maximum and minimum recorded are 114°F and -6°F. The average growing season is 232 days and extends from March 25 to November 12. Frost has occurred as late as April 30 and as early as October 19.

The 68-year (1893-1960) average rainfall at Brownwood (15 miles northeast of the study area) is 27.55 inches. The weighted-mean rainfall on the study area during the 9-year period, 1952-60, was 22.05 inches. Rainfall is generally greatest during the spring and fall months and least during the winter months. About 72 percent of the rainfall occurs during the frost-free period.

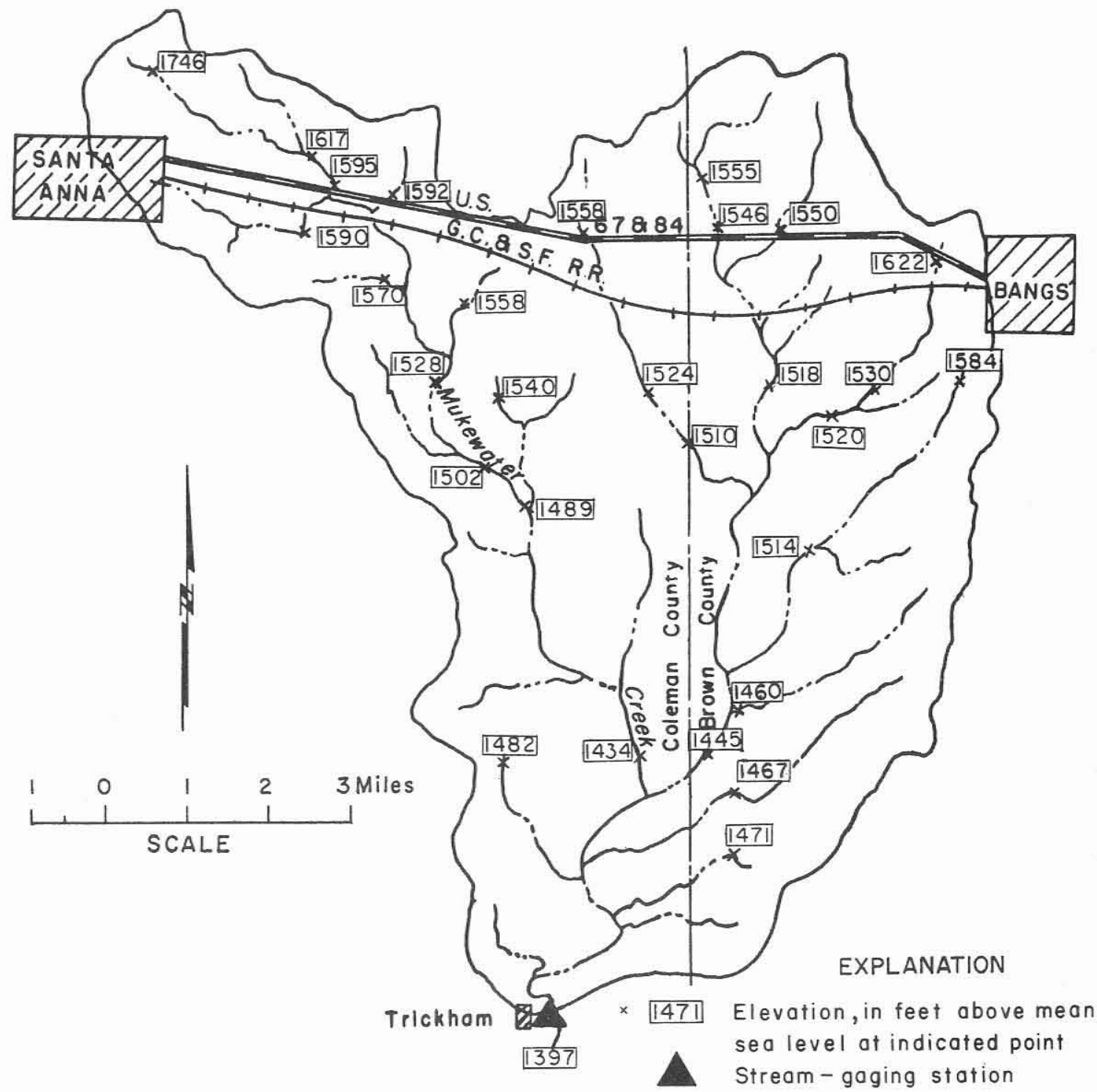
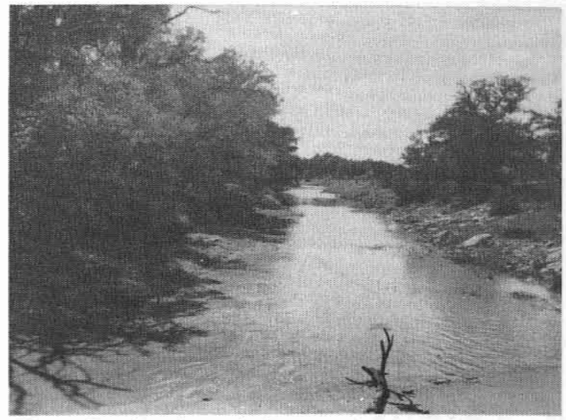


Figure 4

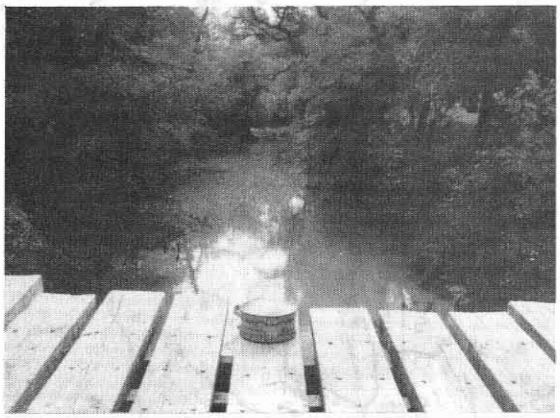
Map of Mukewater Creek Study Area Showing Point Elevations of Stream Channels

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

View of main channel upstream from low-water crossing about 0.6 mile south and 0.9 mile east of proposed site of floodwater-retarding structure 10A.



View of main channel downstream from low-water crossing about 0.6 mile south and 0.9 mile east of proposed site of floodwater-retarding structure 10A.



View of main channel looking downstream from bridge about 3.2 miles north and 1.8 miles west of proposed site of floodwater-retarding structure 10A.

View of main channel looking downstream from bridge about 2.3 miles north and 1.3 miles west of proposed site of floodwater-retarding structure 10A.

View of main channel looking downstream from bridge on county road 0.7 mile south of proposed site of floodwater-retarding structure 10A.

View of main channel looking upstream from bridge 700 feet below stream-gaging station. (Photograph taken July 10, 1962.)

Figure 5

Typical Views of Main Channel in Mukewater Creek
(All photographs taken October 14, 1962, except as noted.)

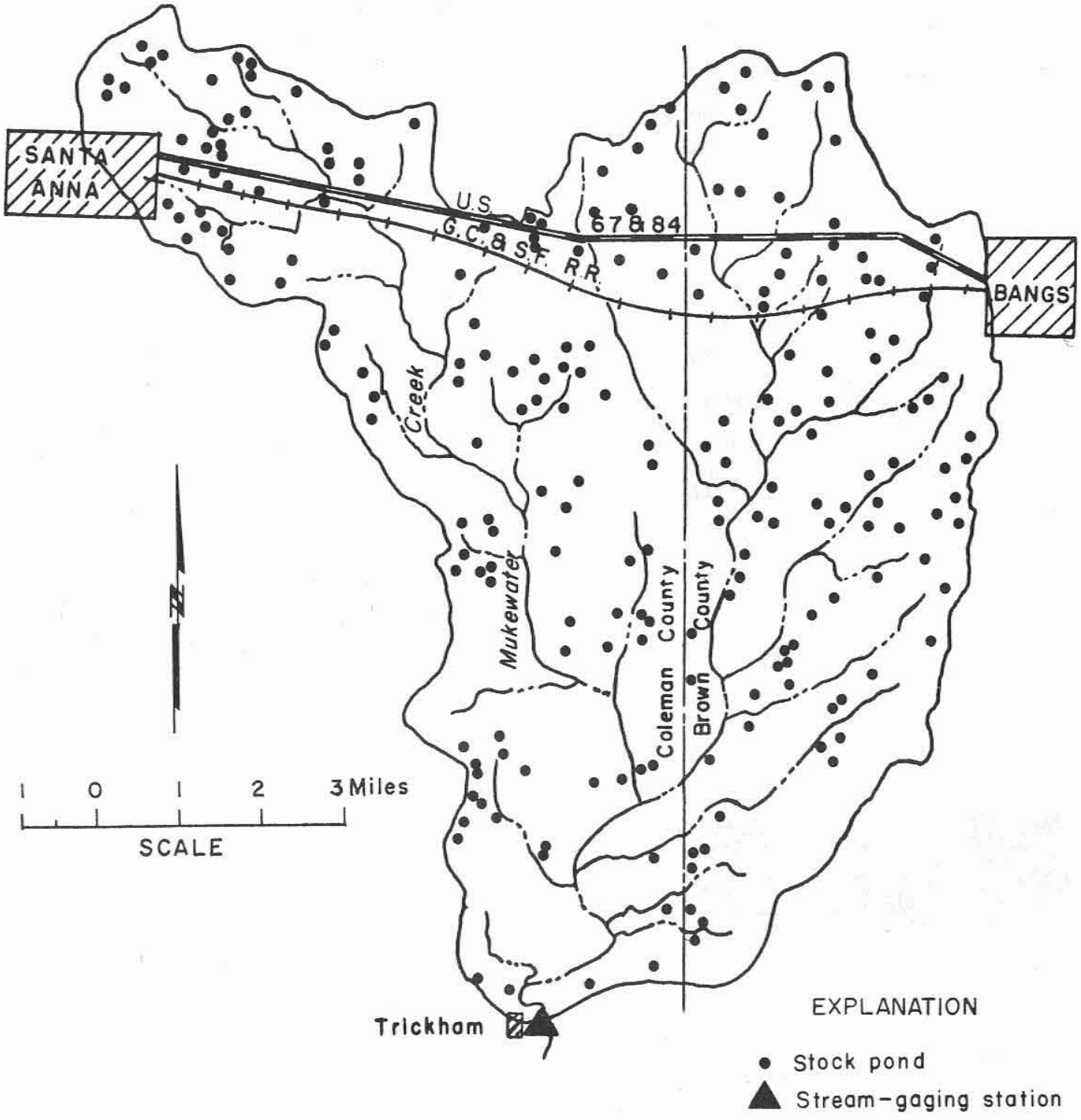


Figure 6
Map of Mukewater Creek Study Area Showing Location of Stock Ponds

U. S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Annual rainfall ranges from about 13 inches to about 45 inches, a large percentage of which sometimes occurs in a single storm. In the storm of April 30 to May 1, 1956, 4.85 inches or 38 percent of the annual rainfall occurred in 5 hours.

Proposed Developments

A system of seven floodwater-retarding structures is planned for this watershed by the U.S. Soil Conservation Service. The seven structures will partly control floodwater from approximately 33.7 of the 70.0 square miles in the study area. These seven structures will have a combined capacity at emergency spillway crest of 7,820 acre-feet, of which 6,770 acre-feet is floodwater-retarding capacity and 1,050 acre-feet is sediment-pool capacity. The above figures were taken from the work plan for Mukewater Creek watershed prepared by the U.S. Soil Conservation Service in March 1955[1/] and revised information furnished by the State Conservationist, U.S. Soil Conservation Service (written communication, H. N. Smith, December 12, 1963). Locations of the proposed structures are shown on Figure 7.

Structures 5 and 5A are designed to operate as a unit and are classified as one structure by the U.S. Soil Conservation Service. The emergency spillway of site 5A drains into site 5. Site 5A has a small amount of floodwater-retarding storage which will drain past site 5 and, therefore, is classified as a separate structure for this report.

Millgate[2/] concluded that seepage from the proposed floodwater-retarding pools would be negligible because the sediments underlying the pools are shale and dense limestone. Furthermore, no pools are proposed in those parts of the watershed where the thin-bedded sandstone and conglomerate crop out.

INSTRUMENTATION AND DATA COLLECTION

Hydrologic data for this report consist of rainfall records at 19 locations within the study area and continuous records of streamflow on Mukewater Creek (Figure 8). Nineteen rain gages were installed in September 1953, and were located in accordance with the United States Weather Bureau (USWB) procedures to provide the best geometric coverage of the study area. Four of the 19 are USWB 8-inch recording rain gages and 15 are USWB 8-inch nonrecording rain gages. Gages were serviced and rainfall measured weekly by employees of the U.S. Soil Conservation Service.

In addition to the rainfall records obtained from the rain gages installed in September 1953, monthly and annual weighted-mean rainfall for the 1952 and 1953 water years were computed using USWB records for Coleman, Brownwood, and Trickham.

[1/] *Work Plan, Mukewater Creek Watershed*, 1955, *Soil Conservation Service*, U.S. Department of Agriculture, Temple, Texas. Structures nos. 5, 5A, 6, 7, and 9 were built during 1961 and no. 10A during 1965 water years.

[2/] M. L. Millgate, geologist, U.S. Geol. Survey: written communication, 1961.

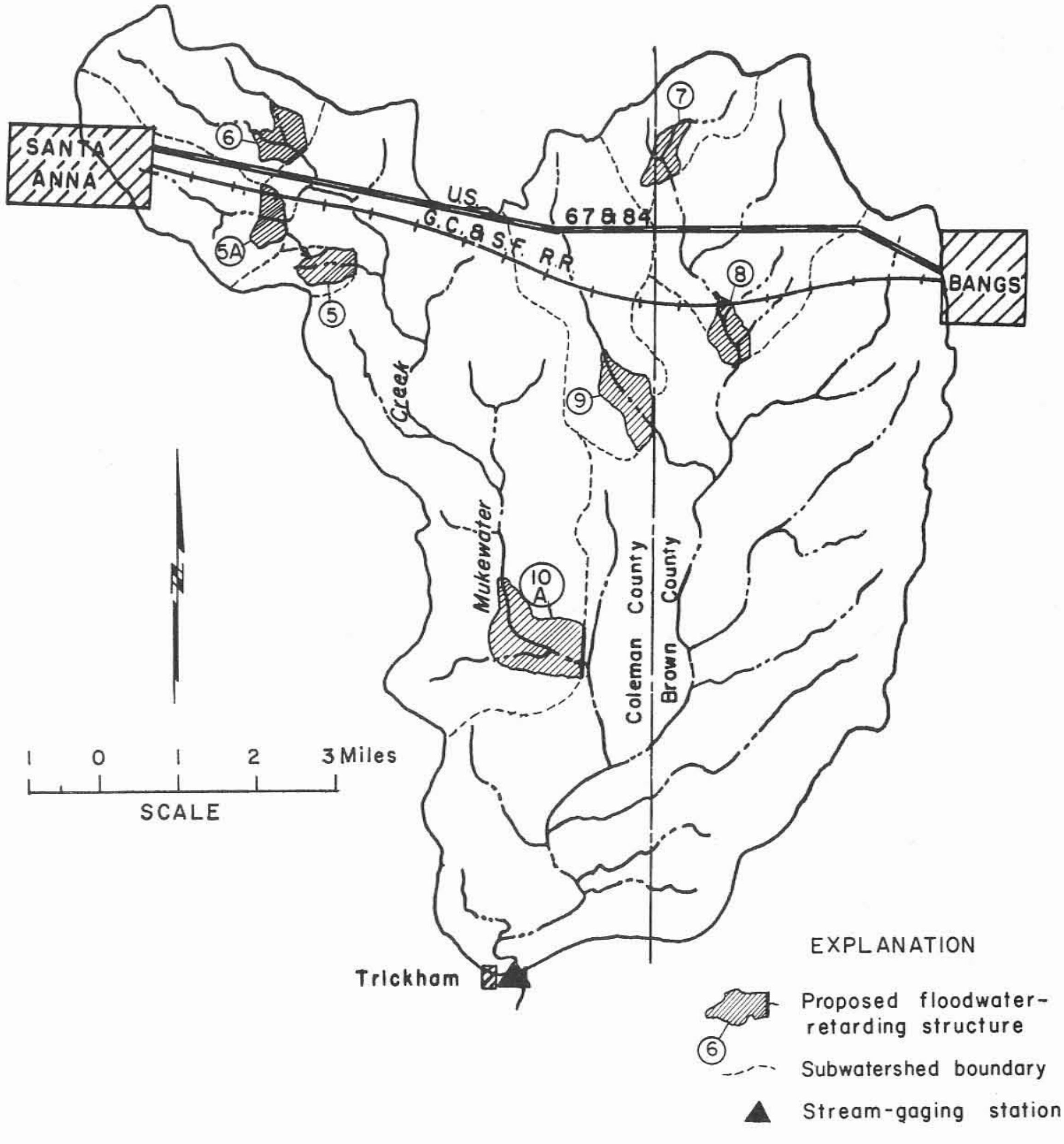


Figure 7

Map of Mukewater Creek Study Area Showing Location of Proposed Floodwater-Retarding Structures

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

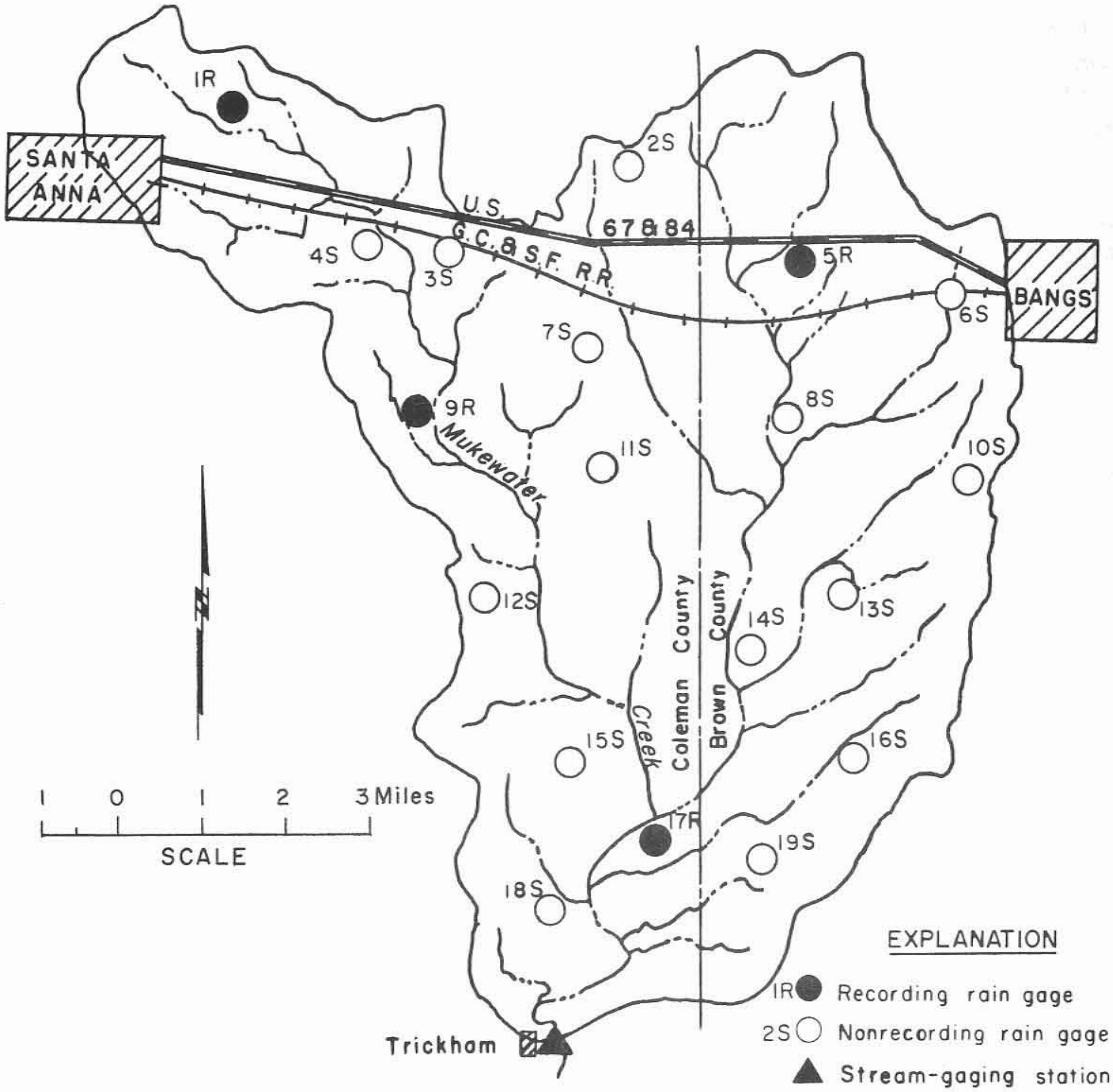


Figure 8

Map of Mukewater Creek Study Area Showing Location of Hydrologic Instrument Installations

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

A continuous water-stage recorder is located at the stream-gaging station, Mukewater Creek at Trickham. Continuous records of stage and discharge measurements at approximately monthly intervals have been obtained since August 28, 1951. Figure 9 shows typical hydrologic instrument installations.

A review of the data collected during the period 1951-60 indicates that data are of excellent quality. Recommendations for changes and additions to the basic data collection program are listed near the end of this report.

Data are presented in this report on the basis of a "water year" period. The water year begins October 1 and ends on September 30, and is designated by the calendar year in which it ends. Thus, the year that ended September 30, 1960, is denoted as the 1960 water year.

Streamflow records collected from this study area are published in the annual series of U.S. Geological Survey Water-Supply Papers. Table 12 is a summary of the rainfall data collected in the study area for the period covered by this report.

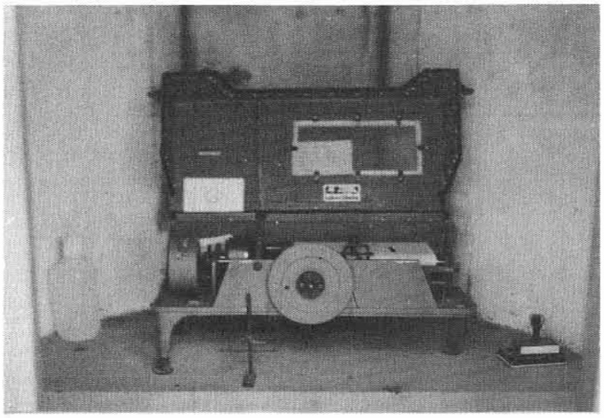
RAIN GAGE NETWORK ANALYSES

One purpose of this report is to determine the minimum instrumentation necessary for making reliable estimates of inflow to the proposed structures. This section will deal with the instrumentation to measure rainfall and consists primarily of rain-gage density analyses.

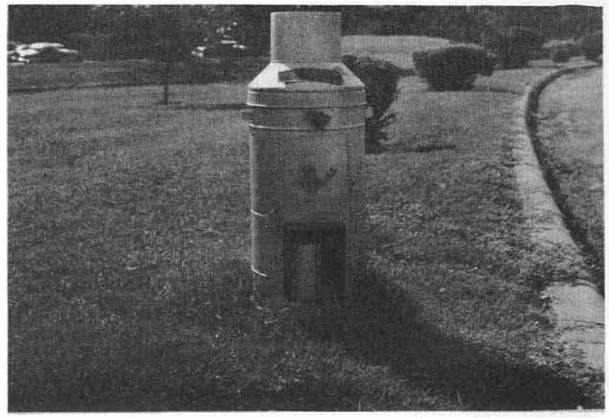
The rain-gage density analyses consist of comparing the average (arithmetic mean) storm rainfall derived for 4, 7, and 10 gages, respectively, with WMR (weighted-mean rainfall) as computed by the Thiessen polygon weighting method using all 19 rain gages. Only those storms with a weighted-mean rainfall of 0.40 inch or greater were considered in these analyses.

For the purpose of this study, a storm is defined as a period of rainfall separated by at least 6 hours of no rainfall. When more than one storm occurs between servicing of gages, individual storm totals for nonrecording gages are based on the nearest recording gage. No corrections are made for the minor evaporation at the nonrecording gages. The distribution of individual storm totals at nonrecording gages based on the recording gages also introduces random errors for unevenly distributed rainfalls. Errors introduced by these two factors are considered insignificant. The weighted-mean rainfall on the study area during the 7-year period 1954-60, used for the rain-gage network analyses, was 23.39 inches; this compares with the 68-year average of 27.55 inches at Brownwood (15 miles northeast of the area).

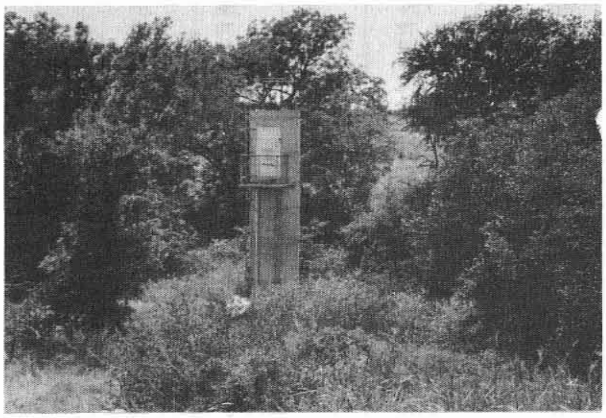
There were 121 storms with a weighted-mean rainfall of 0.40 inch or more. For each series of computations, the rain gages were selected to provide the optimum areal geometric coverage for the specified number of gages. Date of storm, weighted-mean rainfall, and the average rainfall from 4, 7, and 10 gages, respectively, are shown in Table 2. Figures 10, 11, and 12 are plots of weighted-mean storm rainfall versus average storm rainfall of 4, 7, and 10 gages, respectively.



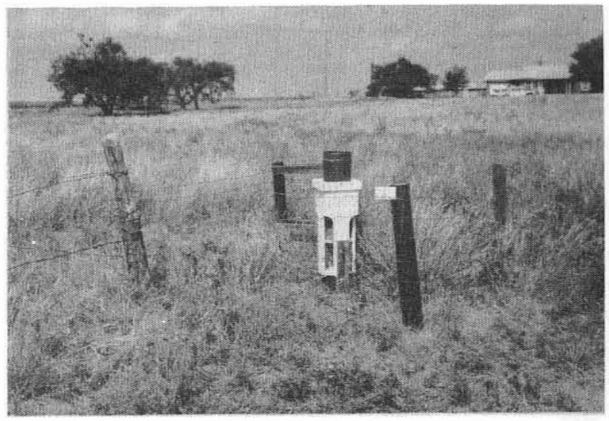
Stream-gaging station recorder in operation. Photograph taken October 14, 1962.



Typical recording rain gage. This photograph taken in Waller Creek watershed in Austin, Texas, October 16, 1962. Same type of recording rain gage is used in Mukewater Creek study area.



View from left bank showing gage structure of stream-gaging station, Mukewater Creek at Trickham, Texas. Photograph taken July 10, 1962.



Typical non-recording rain gage installation. This is rain gage 19-S in study area. Photograph taken October 14, 1962.

Figure 9

Typical Hydrologic Instrument Installations

Table 2.--Storm rainfall computed by weighted-mean rainfall and average of 4, 7, and 10 rain gages for all storms with weighted-mean rainfall exceeding 0.40 inch

Date of storm	Weighted-mean rainfall	Average of 4 gages	Average of 7 gages	Average of 10 gages
Oct. 3-4, 1953	3.94	3.86	3.91	3.90
Mar. 24, 1954	.90	1.00	.88	.95
Apr. 12, 1954	1.17	1.50	1.21	1.26
Apr. 22-23, 1954	.81	.93	.82	.88
Apr. 27, 1954	.63	.72	.63	.69
Apr. 30, 1954	.57	.69	.63	.64
May 11, 1954	1.12	.99	1.05	1.04
June 7, 1954	.60	.55	.67	.63
June 22, 1954	.45	.50	.33	.48
July 31, 1954	1.11	1.12	1.06	1.13
Aug. 31, 1954	.48	.40	.46	.40
Oct. 5, 1954	.90	.99	.91	.88
Oct. 27, 1954	.82	.84	.84	.83
Nov. 14, 1954	.91	.98	.91	.76
Jan. 9, 1955	.48	.49	.48	.48
Feb. 4, 1955	.78	.76	.80	.77
May 10-11, 1955	2.55	2.60	2.70	2.65
May 11, 1955	.58	.57	.59	.60
May 16-17, 1955	.54	.66	.52	.54
May 17, 1955	1.94	2.06	1.95	2.04
May 18-19, 1955	.69	.68	.70	.68
June 4, 1955	.98	1.10	.93	.94
June 6, 1955	.76	.72	.88	.84
June 8, 1955	.67	.73	.66	.64
June 14-15, 1955	1.16	1.25	1.16	1.13
July 16-17, 1955	2.16	2.07	2.15	2.12
July 17-18, 1955	1.44	1.42	1.42	1.35
Aug. 30, 1955	.71	.47	.60	.54
Sept. 22, 1955	2.82	2.81	2.84	2.88
Sept. 24, 1955	.42	.55	.37	.37
Nov. 30, 1955	.51	.51	.51	.52
Jan. 17, 1956	.88	.87	.86	.86
Jan. 21, 1956	.56	.54	.52	.52
Apr. 21, 1956	.48	.46	.45	.46
Apr. 30, 1956	.67	.58	.72	.68
Apr. 30-May 1,1956	4.85	4.85	5.01	4.79
May 23-24, 1956	.82	.83	.82	.81
Aug. 19, 1956	.69	.73	.56	.63
Aug. 28, 1956	.67	.69	.56	.64
Sept. 6, 1956	.45	.22	.57	.48
Oct. 15, 1956	.69	.64	.69	.70
Oct. 18, 1956	.96	.90	.98	.97
Oct. 30, 1956	.77	.62	.78	.83
Nov. 4, 1956	.55	.61	.56	.55
Dec. 18-19, 1956	1.06	1.03	1.07	1.04
Feb. 16, 1957	.46	.48	.44	.46
Mar. 10, 1957	.51	.48	.51	.51
Mar. 20, 1957	1.02	.85	.99	1.02
Apr. 18-19, 1957	1.84	1.87	1.83	1.86
Apr. 22-23, 1957	1.18	1.23	1.20	1.18
Apr. 26, 1957	3.19	3.56	3.27	3.28
May 4, 1957	.41	.42	.37	.40
May 9, 1957	.71	.70	.71	.71
May 11, 1957	1.51	1.28	1.52	1.52
May 12, 1957	.43	.50	.47	.42
May 13, 1957	.79	.74	.81	.80
May 17, 1957	1.31	1.29	1.30	1.30
May 18, 1957	.76	.73	.75	.75
May 23, 1957	1.11	1.24	1.16	1.14
June 1, 1957	.63	.66	.58	.59
June 5, 1957	.43	.54	.49	.38
June 12, 1957	0.96	1.08	1.06	0.96
July 23, 1957	.60	.60	.54	.53
Aug. 5, 1957	.46	.60	.56	.60
Sept. 11, 1957	.73	.68	.73	.69
Oct. 13, 1957	1.51	1.41	1.48	1.50
Oct. 14, 1957	1.07	1.12	1.05	1.04
Oct. 15, 1957	.49	.52	.47	.47
Nov. 5, 1957	.77	.72	.80	.76
Nov. 24, 1957	.97	.97	.98	.96
Dec. 24-25, 1957	.95	.93	.94	.95
Jan. 4-5, 1958	.67	.64	.65	.68
Jan. 22-23, 1958	.76	.73	.77	.78
Feb. 21, 1958	.59	.58	.59	.60
Feb. 22, 1958	1.58	1.63	1.58	1.60
Mar. 6, 1958	.67	.66	.60	.65
Mar. 12, 1958	.48	.42	.44	.46
Apr. 13, 1958	1.07	.98	1.05	1.06
Apr. 20, 1958	.81	.85	.84	.82
May 2, 1958	.75	.83	.77	.73
May 13, 1958	1.22	1.04	1.22	1.23
June 21, 1958	2.00	2.02	2.07	2.00
Aug. 23-24, 1958	2.33	2.54	2.49	2.33
Sept. 6, 1958	.43	.39	.42	.41
Sept. 15-16, 1958	.66	.69	.73	.74
Sept. 19, 1958	.53	.47	.56	.54
Nov. 14, 1958	.84	.80	.86	.87
Apr. 10, 1959	.72	.75	.70	.72
May 15, 1959	1.52	1.48	1.62	1.54
May 22, 1959	.74	.68	.77	.78
June 1, 1959	1.70	1.55	1.75	1.64
June 2, 1959	.49	.44	.51	.47
June 3, 1959	1.15	1.19	1.27	1.16
June 3-4, 1959	2.42	2.47	2.51	2.46
June 23-24, 1959	.61	.59	.65	.59
June 25-26, 1959	2.54	2.24	2.55	2.45
July 19, 1959	1.85	1.98	1.85	1.83
July 20, 1959	.98	.98	.96	.95
July 21, 1959	3.36	3.46	3.37	3.32
Aug. 8, 1959	.46	.54	.44	.49
Aug. 31, 1959	.73	.77	.68	.75
Sept. 30, 1959	1.24	1.26	1.44	1.33
Oct. 3-4, 1959	4.18	4.14	4.10	4.21
Oct. 13, 1959	.89	.88	.86	.89
Nov. 3, 1959	.57	.57	.59	.56
Dec. 14-15, 1959	.64	.60	.59	.60
Dec. 16, 1959	.61	.62	.59	.60
Dec. 31, 1959	1.08	1.06	1.07	1.08
Jan. 4-5, 1960	1.31	1.30	1.30	1.32
Jan. 12, 1960	.41	.43	.36	.40
Jan. 13, 1960	.86	.77	.86	.87
Feb. 2-3, 1960	.89	.83	.96	.92
Apr. 24, 1960	.82	.66	.70	.68
Apr. 25, 1960	.69	.59	.69	.64
Apr. 29, 1960	.56	.44	.60	.56
May 27, 1960	.48	.59	.49	.48
July 16, 1960	.57	.38	.73	.70
Aug. 9, 1960	1.22	1.23	1.27	1.25
Aug. 10, 1960	.71	.67	.65	.66
Sept. 23, 1960	1.08	1.24	1.08	1.08
Sept. 24, 1960	.54	.48	.55	.56
7-year totals	126.51	126.42	127.48	126.34

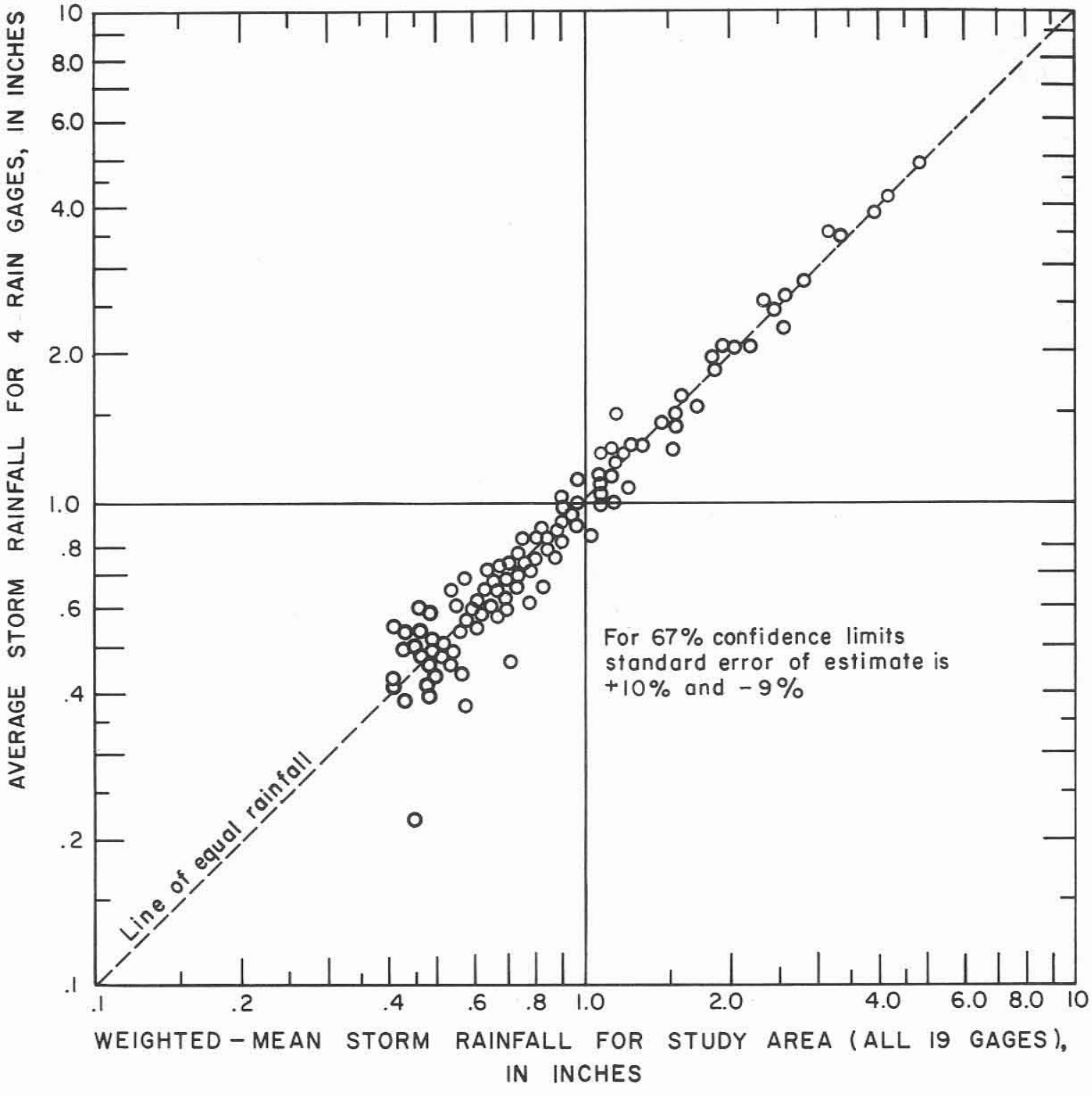


Figure 10

Comparison of Concurrent Storm Rainfall, Average for 4 Gages and Weighted-Mean Rainfall for Mukewater Creek Study Area

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

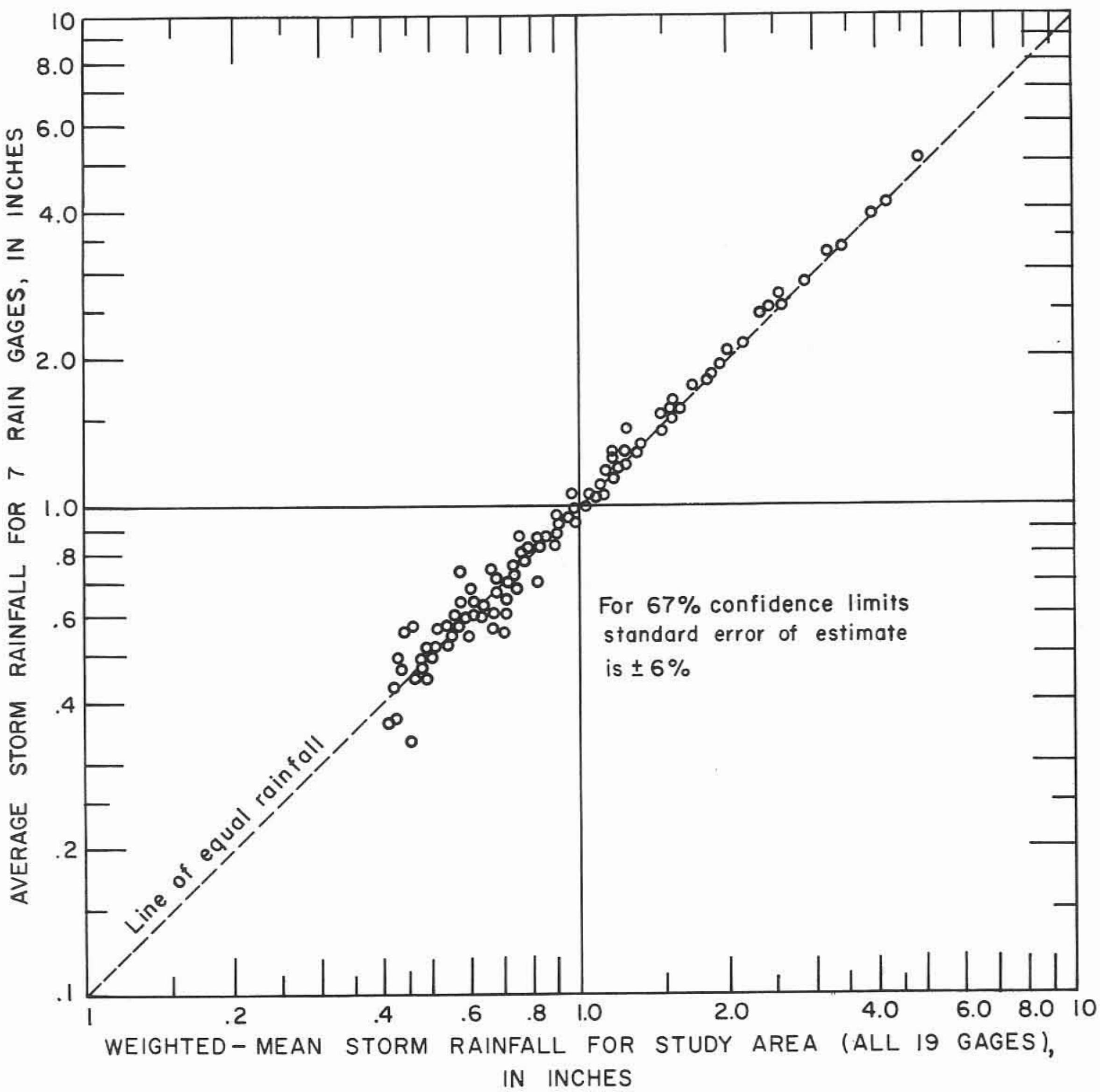


Figure 11

Comparison of Concurrent Storm Rainfall, Average for 7 Gages and Weighted - Mean Rainfall for Mukewater Creek Study Area

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

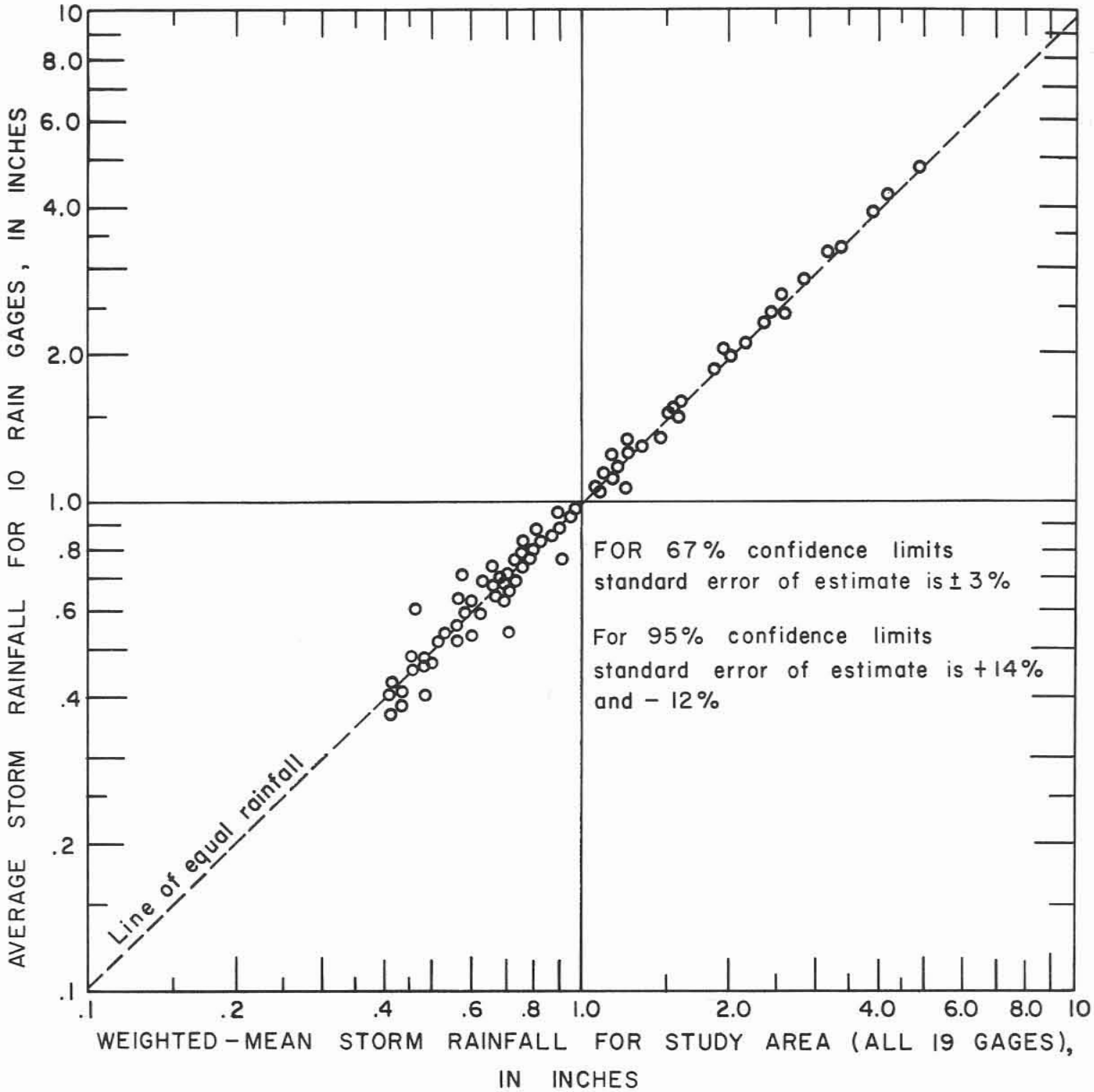


Figure 12

Comparison of Concurrent Storm Rainfall, Average for 10 Gages and Weighted-Mean Rainfall for Mukewater Creek Study Area

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

The following conclusions may be drawn from Table 2 and Figures 10, 11, and 12:

1. Using the arithmetic average rainfall of 4 gages, for 67 percent confidence limits (67 percent of the storms), storm rainfall may be determined within +10 percent and -9 percent of the weighted-mean rainfall as determined from 19 rain gages.

2. Using the arithmetic average rainfall of 7 gages, for 67 percent confidence limits, storm rainfall may be determined within ±6 percent of the weighted-mean rainfall as determined from 19 rain gages.

3. a. Using the arithmetic average rainfall of 10 gages, for 67 percent confidence limits, storm rainfall may be determined within ±3 percent of the weighted-mean rainfall as determined from 19 rain gages.

b. Using the arithmetic average rainfall of 10 gages, for 95 percent confidence limits, storm rainfall may be determined within +14 percent and -12 percent of the weighted-mean rainfall as determined from 19 rain gages.

4. The scatter or deviation from the line of equal rainfall above 1.5 inches is very small, particularly for the average of 7 and 10 gages.

5. Maximum deviations occurred when weighted-mean rainfall was less than 1 inch. This would be expected owing to the uneven distribution of rainfall from small thunderstorms which occur in this area.

6. The principal conclusion from the analyses is that for computation of total rainfall on the watershed the number of rain gages in this watershed could be reduced considerably, provided that an occasional large error in storm rainfall for minor storms would not be serious for the purpose of the data. For long-term rainfall, Table 2 shows that the 7-year totals computed by the four methods are practically identical.

7. For determination of rainfall on the separate drainage areas of the proposed floodwater-retarding structures and for determination of precipitation on the pools created by the structures, all 19 gages will be necessary. This is only one example of the need for many rain gages where rainfall distribution rather than total rainfall is desired.

FLOOD-FREQUENCY ANALYSES

Available data concerning the magnitude and frequency of floods in the study area are presented in this section. Available for study are 9 years (1952-60) of continuous streamflow record, one historical peak stage, and the annual maximum peak discharge for the 1951 water year. The peak stage in 1927 is reported to be the highest since at least 1919. As no other floods approaching the magnitude of the 1927 flood were reported by local residents, it was assumed that the flood of May 1, 1956, was the second highest since 1919.

To determine a flood-frequency curve for the Mukewater Creek study area, plotting positions for floods were determined using the U.S. Geological Survey method as outlined by Dalrymple (1960). The formula used is

$$T = \frac{n+1}{m}, \tag{2}$$

where T is recurrence interval, in years,
n is number of years of record, and
m is magnitude of flood, the highest being 1.

The plotting positions for the two highest floods were determined using n = 42. For all floods occurring during the period of streamflow record, except for the May 1, 1956 flood, n = 10 for the annual series and n = 9 for the partial-duration series. Table 3 lists all floods above 600 cfs (cubic feet per second).

Figure 13 is a plot of annual flood data and the resulting flood-frequency curve. Also shown on Figure 13 is a flood-frequency curve for the study area based on a regional flood-frequency analysis by Patterson (1963). A regional flood-frequency analysis consists primarily of a determination of the flood-frequency characteristics of a hydrologically homogeneous region. These characteristics are expressed as curves in terms of the discharge ratio of a given flood to the mean annual flood and recurrence interval; and, mean annual floods expressed as a function of the drainage area.

Figure 14 is a plot of the partial-duration series data for the study area. Also shown is the flood-frequency curve based on the regional analysis.

A study by Benson (1952) shows that 12 years of record are required to define the mean annual flood within 25 percent if correct results are expected 95 percent of the time. With 10 years of annual flood data and 42 years of historical record, the flood-frequency curve for the study area is reasonably well defined. The curve based on actual data indicates somewhat higher discharges for a given recurrence interval than does the curve based on regional analyses. The regional curve is not well defined by data from watersheds which have less than 100 square miles. The regional curve indicates a mean annual flood (2.33 years recurrence interval) of 1,650 cfs compared to 2,200 cfs from the basic-data curve. This comparison would indicate that the regional curve should be used with caution on watersheds with less than 100 square miles.

UNIT HYDROGRAPH ANALYSES

A study was made of unit hydrographs of storms in the Mukewater Creek study area before development with the anticipation of comparing them with hydrographs after the watershed has been developed. One such comparison would be to compare the rainfall-runoff relationship prior to and after the construction of floodwater-retarding structures. This comparison can be made by first estimating the probable runoff from a storm by use of the coaxial rainfall-runoff relationship as developed later in this report. A synthetic hydrograph could then be constructed by using the estimated runoff and a pre-development unit hydrograph. This synthetic hydrograph could then be compared with the actual hydrograph at the stream-gaging station. This and other comparisons should enable a better determination of the effects of watershed development.

The unit hydrograph is the hydrograph of direct runoff resulting from 1 inch of precipitation excess occurring during a unit time. Since the presentation of the unit hydrograph concept by L. K. Sherman (1932), it has gained

Table 3.--Flood data for Mukewater Creek at Trickham, Texas

Drainage area 70.0 square miles. Period of record 1951-60.
Flood data for momentary peak discharges greater than 600 cfs.

WATER YEAR	DATE	GAGE HEIGHT (Feet)	DISCHARGE		ANNUAL FLOODS		PARTIAL DURATION SERIES		REMARKS
			CFS	RATIO TO $Q_{2.33}$	ORDER (M)	RECURRENCE INTERVAL (Years)	ORDER (M)	RECURRENCE INTERVAL (Years)	
1927	--	*18	†22,000	--	1	43	1	43	Maximum since at least 1919.
1951	May 22, 1951	11.40	4,900	--	4	2.75	--	--	
1952	Apr. 22, 1952	4.68	708	--	--	--	26	.38	
	May 18, 1952	4.69	708	--	--	--	25	.40	
	May 24, 1952	5.82	1,140	--	8	1.38	17	.59	
1953	Mar. 9, 1953	4.64	690	--	--	--	27	.37	
	May 12, 1953	5.25	920	--	9	1.22	20	.50	
1954	Oct. 4, 1953	6.79	1,620	--	6	1.83	11	.91	
	Mar. 24, 1954	6.33	1,360	--	--	--	15	.67	
	May 11, 1954	4.68	708	--	--	--	24	.42	
1955	May 10, 1955	10.85	4,320	--	5	2.20	5	2.00	
	May 18, 1955	8.52	2,460	--	--	--	8	1.25	
	June 5, 1955	4.70	727	--	--	--	23	.43	
	June 7, 1955	5.62	1,060	--	--	--	18	.56	
	June 9, 1955	4.51	671	--	--	--	28	.36	
	June 15, 1955	7.54	2,040	--	--	--	9	1.11	
	July 18, 1955	7.01	1,680	--	--	--	10	1.00	
	Sept.23, 1955	6.71	1,560	--	--	--	12	.83	
1956	May 1, 1956	15.83	15,000	--	2	21.5	2	21.5	Second highest since 1919.
1957	Mar. 20, 1957	4.44	628	--	--	--	30	.33	
	Apr. 19, 1957	5.06	855	--	--	--	22	.45	
	Apr. 23, 1957	5.21	915	--	--	--	21	.48	
	Apr. 26, 1957	12.45	6,760	--	2	5.50	2	5.00	
	May 11, 1957	8.17	2,580	--	--	--	7	1.43	
	May 18, 1957	9.27	3,430	--	--	--	6	1.67	
	May 24, 1957	6.25	1,470	--	--	--	13	.77	
1958	Aug. 24, 1958	4.57	670	--	10	1.10	29	.34	
1959	June 2, 1959	5.10	947	--	--	--	19	.53	
	June 4, 1959	11.26	5,820	--	--	--	4	2.50	
	June 26, 1959	6.08	1,370	--	--	--	14	.71	
	July 21, 1959	11.90	6,620	--	3	3.67	3	3.33	
1960	Oct. 4, 1959	5.57	1,150	--	7	1.57	16	.62	
	Jan. 5, 1960	4.30	620	--	--	--	31	.32	
	Jan. 14, 1960	4.27	610	--	--	--	32	.31	

*From information by local residents.
†Estimated.

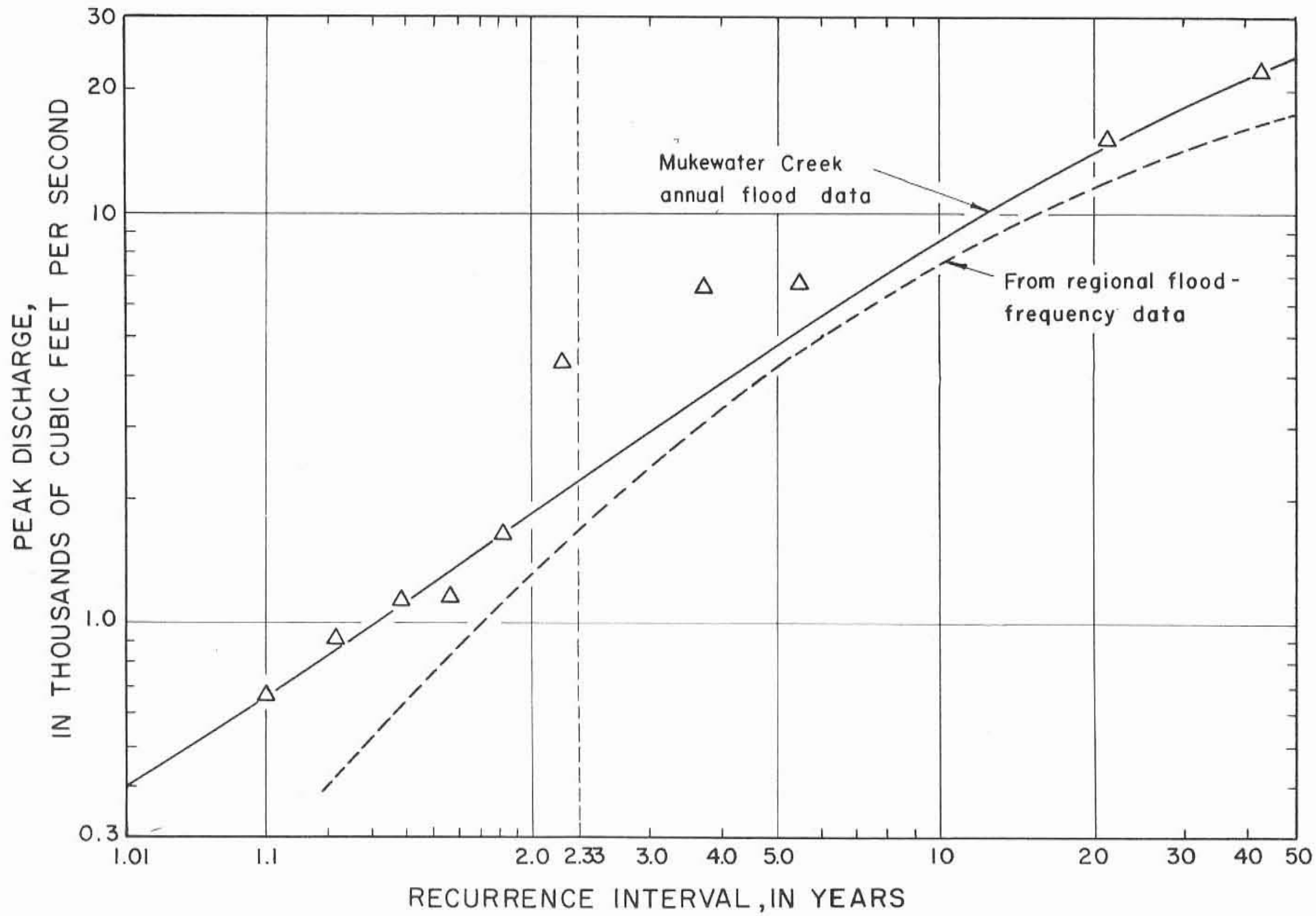


Figure 13

Flood-Frequency Curve for Mukewater Creek at Trickham, Texas, Based on Annual Floods

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

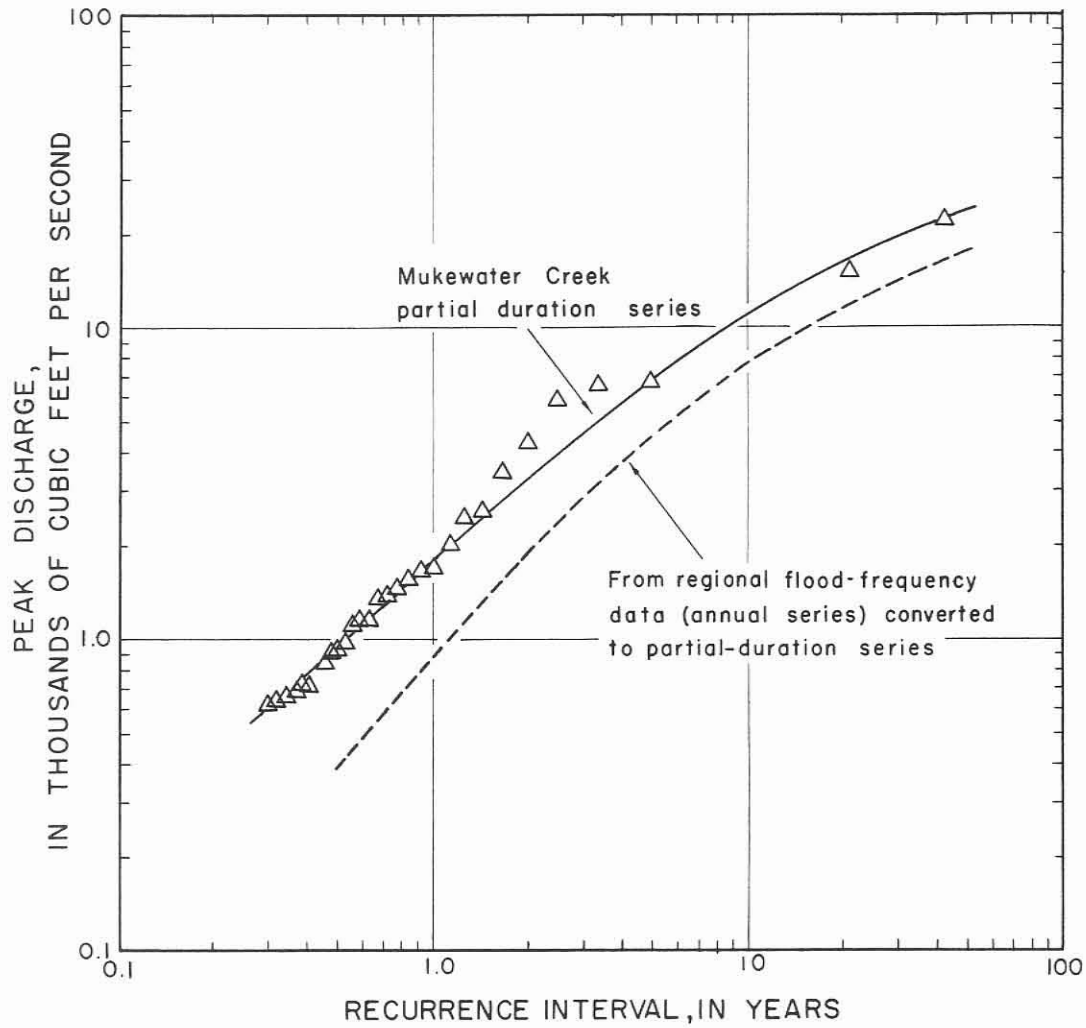


Figure 14

Flood-Frequency Curve for Mukewater Creek at Trickham, Texas, Based on Partial-Duration Series

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

wide acceptance in hydrologic circles as a valuable tool in evaluating a few of the hydrologic characteristics of a watershed. The principles involved in the unit hydrograph relationship are clearly stated in U.S. Geological Survey Water-Supply Paper 772.

As Mitchell (1948) pointed out, the unit hydrograph should not be used to predict the precipitation excess (storm runoff) from a given rainfall; it is simply a means of determining the time distribution of precipitation excess. The unit hydrograph and the rainfall-runoff (volume of runoff) relationship are arrived at by two entirely different analytical processes. The unit hydrograph for a watershed is determined by reducing selected hydrographs to unit hydrographs. The rainfall-runoff relation for a watershed is determined by relating rainfall and other factors (antecedent conditions, intensity of rainfall, vegetal cover) to volume of runoff. If both of these hydrologic characteristics are known for a watershed, the storm hydrograph for any storm can be reproduced.

Only those storms with runoff of 0.25 inch or more were investigated for the unit hydrograph of this study area. Of these infrequent storms, some were not used because of uneven distribution of rainfall or nonuniformly shaped hydrographs. Judgment must be used in determining what constitutes a uniformly distributed storm. By most criteria, no truly uniform storm occurred during the 7-year period of record; nevertheless, 11 storms were selected which met the criteria of reasonably uniform hydrographs and rainfall. Storm hydrographs for these were reduced to unit hydrographs. The unit hydrographs were plotted to determine whether or not there was a correlation between duration of rainfall, time of rise, and unit hydrograph peak. Time of rise is defined as the time interval on the rising limb between the minimum and maximum unit hydrograph discharge. The plot of the 11 unit hydrographs showed no reliable correlation between these factors. Of the 11 unit hydrographs, the six shown on Figure 15 were selected as being representative of the entire group investigated. Table 4 lists several important parameters for each of the selected six storms.

Table 4.--Parameters for six storms selected for unit hydrograph study

Date of storm	Duration of rainfall (hours)	Weighted-mean rainfall (inches)	Direct runoff (inches)	Peak of unit hydrograph (cfs)	Time of rise (hours)
Oct. 3-4, 1953	12.5	3.94	0.49	3,290	14.5
June 14-15, 1955	.25	1.16	.40	5,180	7.0
Apr. 30-May 1, 1956	5.0	4.85	2.16	6,950	6.5
May 11, 1957	2.0	1.51	.71	3,630	11.0
May 23, 1957	1.25	1.11	.32	4,560	11.5
June 3-4, 1959	2.0	2.42	1.20	4,750	7.0

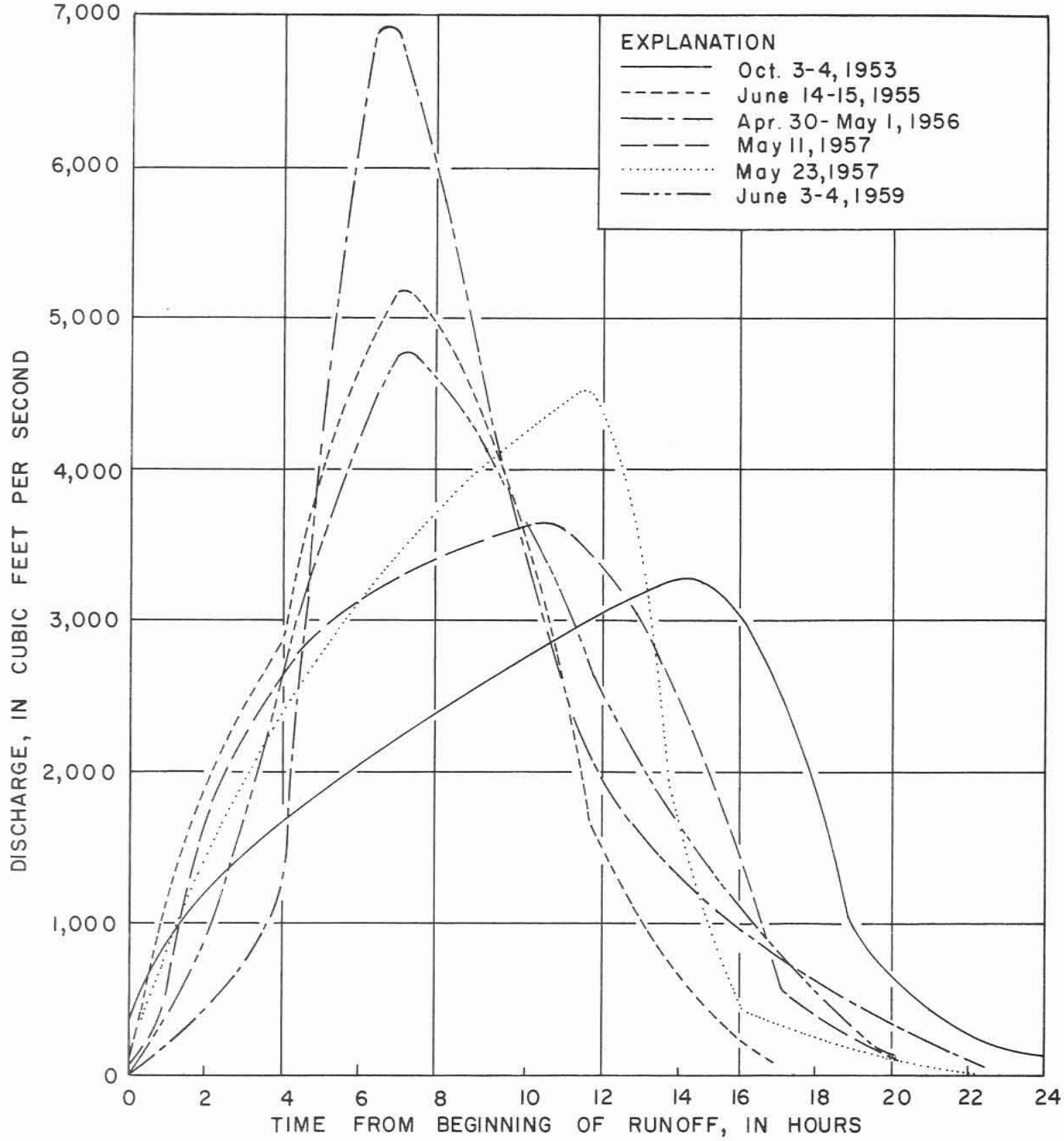


Figure 15

Selected Unit Hydrographs of the Study Area (Mukewater Creek at Trickham, Texas)

U.S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Brater (1940), in a study on very small watersheds ranging from 4.24 to 1,876.7 acres, concluded that any storm with sufficient intensity to produce surface runoff would produce a consistent unit hydrograph provided that the duration of rainfall was equal to or less than the time of rise. Subsequent discussions of Brater's paper by Franklin F. Snyder and L. K. Sherman indicated their disagreement with Brater's conclusion. They believed that time of rise of the unit hydrograph was not independent of duration of rainfall, even though the duration did not exceed the time of rise.

Table 4 and Figure 15 show that the storms of May 11, 1957, and June 3-4, 1959, both having a duration of rainfall of 2 hours, produced markedly different unit hydrographs. The two storms listed that occurred in 1957 appear to be out of character with the remainder of the storms; however, other storms with the same characteristics were found. The storm of October 3-4, 1953 should logically have a longer time of rise and lower unit hydrograph peak since the storm duration was quite long. The unit hydrograph of this storm bears out this reasoning.

It is also of interest to note that the storm of April 30-May 1, 1956 produced a unit hydrograph peak considerably greater than any of the other storms. This storm produced the maximum peak discharge during the period of record and the second highest peak since at least 1919. Hydrologists generally agree that extreme floods will produce somewhat higher unit hydrograph peaks than those produced by ordinary storms. According to Snyder (1938), extreme care must be exercised in applying unit hydrographs derived from ordinary storms to extreme storms. Hydrologists should also be cautious in attempting to apply unit hydrographs to storms with nonuniform rainfall intensity on a drainage area the size of the Mukewater Creek watershed. A small drainage area is more likely to reflect variable rainfall intensities in the hydrograph than would a larger drainage area.

Generally the time base used in unit hydrograph studies is the duration of rainfall excess (runoff). In order to determine a duration of runoff, it is necessary to have a corresponding infiltration capacity curve. This in itself presents a difficult problem. For this unit hydrograph study, duration of rainfall was used as a time base.

It is probable that further analysis of the hydrographs for the study area taking into consideration other factors would produce uniform unit hydrographs. It would seem logical to investigate the relationship between the unit hydrograph and varying conditions of antecedent soil moisture, vegetal cover, natural depression storage, and rainfall intensity. An analysis such as this is beyond the scope of this report; however, it seems to be an excellent problem for further investigation.

RELATING RAINFALL AND RUNOFF

Discussion of Methods

Rainfall-runoff relationships for small drainage areas are important to agencies concerned with the design of highway bridges, culverts, storm sewers, urban planning, water-supply systems, and other water-use and water-control projects. Information on such relationships is not as available for small watersheds as for large watersheds. For some projects, only extremes are important, whereas for water-supply projects, the entire yield of a watershed is necessary. The purpose of this section is to analyze and interpret the various factors affecting the rainfall-runoff relationship for the Mukewater Creek study area.

This rainfall-runoff relationship may be used later in evaluating the effect of the floodwater-retarding structures built during 1961 water year and later on the hydrologic characteristics of the watershed. This can be accomplished, when sufficient hydrologic data have been obtained, by comparing runoff after structures are built with runoff estimated from the rainfall-runoff relationship derived in this report.

The relationship between rainfall and resulting runoff is a problem which thus far defies exact mathematical solution. Numerous methods of estimating the runoff resulting from rainfall have been devised. Among the more popular ones are the rational formula, regression analysis, simple rainfall versus runoff plots, and multiple correlation analysis.

Probably the most widely used method is the rational formula,

$$Q = CIA, \tag{3}$$

where Q is peak flow in cfs,
C is a constant dependent upon drainage-area characteristics (primarily imperviousness of underlying material),
I is intensity of rainfall in inches per hour, and
A is drainage area in acres.

This formula is restrictive in that it is used only to predict peak discharge, not the total yield. It is also important to realize the basic premise of this formula is that the entire watershed is contributing and that the rate of runoff equals a percentage C of the rainfall intensity (Rouse, 1950). This would require that the storm duration exceed the "time of concentration of the watershed." The time of concentration of the watershed is generally defined as the time required for a particle of water to travel from the most remote portion of the watershed to the outlet. Storms with durations exceeding the time of concentration are rare in the Mukewater Creek watershed. Use of this formula is practical only on very small watersheds, and it is primarily applicable to urban areas where the cover on the watershed does not change materially because of seasonal effects. This method is considered to be impractical for use on rural watersheds such as the Mukewater Creek study area.

Regression techniques and simple rainfall-runoff plots fail to take into consideration enough of the variables which affect the rainfall-runoff relation in this study area.

Of the several methods advanced by hydrologists, it appears that the multiple-correlation method as outlined by Kohler and Linsley in U.S. Weather Bureau Research Paper 34 (1951) is most suitable for determining the relationship between rainfall and runoff. Therefore, it was used in this report.

Multiple-Correlation Analyses

The amount of surface or storm runoff resulting from a given rainfall is dependent upon numerous factors which include: intensity, duration, distribution, and total amount of rainfall; antecedent soil moisture conditions; surface and subsurface geology; topography; vegetal cover; land-management practices; and seasonal effects. For a particular watershed, topography and surface and subsurface geology remain essentially constant. Variations in land-management practices during the period of record did not produce detectable variations in the runoff characteristics of the study area. Vegetal cover varies and cannot be evaluated for each storm with available data; however, part of the variation will be compensated for by adjusting for the seasonal effects. This leaves intensity, duration, and areal distribution of rainfall; total storm rainfall; antecedent soil moisture conditions; and seasonal effects as variables that could be analyzed in arriving at a general rainfall-runoff relationship.

The procedure used for this report was to formulate a general solution using antecedent conditions, seasonal effects, duration, and total storm rainfall for storms which had uniform areal distributions.

Nonuniform areal distribution of rainfall was accounted for by dividing the study area into subareas and computing the contribution of each subarea to the total runoff hydrograph. Duration and total storm rainfall were used as variables, thereby indirectly making rainfall intensity also a variable. Storms which were reasonably uniform over the study area both in total rainfall and in time and areal distribution, and for which hydrographs could be isolated, were used to construct a multiple-correlation diagram. A total of 30 storms of this nature were used. A storm which is truly uniform throughout the area both in time and rainfall depth was found to be a rare occurrence. Judgment must be used in determining what constitutes a "reasonably uniform" storm. Table 12 shows the wide variation in individual rain-gage catch for a single storm.

The variables that represent the antecedent conditions are labeled the antecedent precipitation index (API). Because the amount and rate of infiltration largely depends on this factor, a measurement of soil moisture conditions prior to each storm would be desirable. The API primarily reflects the antecedent soil moisture conditions. In computing the API, the soil moisture was assumed to be depleted at an exponential rate during periods of no precipitation. The formula used for computing the API at any time is

$$API_t = API_o K^t, \tag{4}$$

where API_o is initial antecedent precipitation index,

API_t is antecedent precipitation index t days after the API_o determination, and

K is a recession factor depending upon watershed characteristics.

Studies by M. A. Nations[3] on a watershed near this study area found a value for "K" of 0.80. Because this study area is in a subhumid region, potential evapotranspiration would be large; therefore, it seems that 0.80 is a reasonable value and it was used.

Because the K value is largely a reflection of the potential evapotranspiration, and evapotranspiration is primarily a seasonal function, API and month

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[3] Nations, M. A., 1959, Multiple correlation of rainfall and other factors to runoff: Unpublished Master's Thesis, The University of Texas, Austin, Texas.

of the year are grouped together in the correlation diagram (Figure 16). This appears to be a logical grouping of variables as the month of the year would also reflect farming practices and vegetal cover.

The value of API_0 was computed by starting with the first storm used for analysis and going back in time to that storm which would have no effect on API_0. The formula for computing API_0 is

$$API_0 = K^{t_1}P + K^{t_2}P_2 + K^{t_3}P_3 + \ldots K^{t_n}P_n \,, \tag{5}$$

where P is the precipitation occurring on the specified date. Precipitation for the 30-day period prior to installation of rain gages in the study area was computed on the basis of rainfall at standard U.S. Weather Bureau gages at Trickham, Coleman, and Brownwood. For an exacting API computation, runoff should be subtracted from the precipitation because it does not add to the residual soil moisture. However, the minor improvements gained do not justify the added computations (Kohler, Linsley, and Paulhus, 1958); therefore, total precipitation was used for API computations.

Duration of a storm is defined as that period in which at least 80 percent of the rainfall occurred. This definition is used because rainfall frequently begins slowly or tapers off near the end of the storm. If the total time of rainfall for such storms was used, it would not accurately reflect the duration of the runoff-producing portion of the storm. For storms which exhibited a relatively constant intensity, the total time of rainfall was used for duration.

Total storm rainfall was computed by applying the Thiessen polygon weighting technique. Storm runoff, in inches, was computed from the total discharge for each storm as determined at the stream-gaging station, Mukewater Creek at Trickham. Normally, there is no base flow in this study area; therefore, the problem of separating base flow from storm runoff at the stream-gaging station was virtually nonexistent. When small flows were present preceding the storm analyzed, they were subtracted from the storm runoff.

A graphical coaxial rainfall-runoff relation was constructed using data shown for the 30 storms in Table 5. The results of this relation are shown on Figure 16. Any graphical correlation with five variables requires considerable trial and error work for a solution. The solution shown on Figure 16 is by no means unique. A different shape for any one set of curves would require a change in shape of the other curves involved. The solution shown is the one which best fits the data obtained for the 30 storms. Once the rainfall-runoff relation has been established, it is comparatively simple to estimate storm runoff from rainfall. In order to use this rainfall-runoff relation, it is necessary to determine four factors for the storm in question: API, month of year, duration of rainfall, and storm rainfall.

Effects of Rainfall Distribution

Runoff Estimates Considering Distribution

Rainfall totals at different gages often show large variations for individual storms. For this reason, it is desirable to account for areal and time distribution of rainfall for individual storms. A 2-inch storm on one-half of

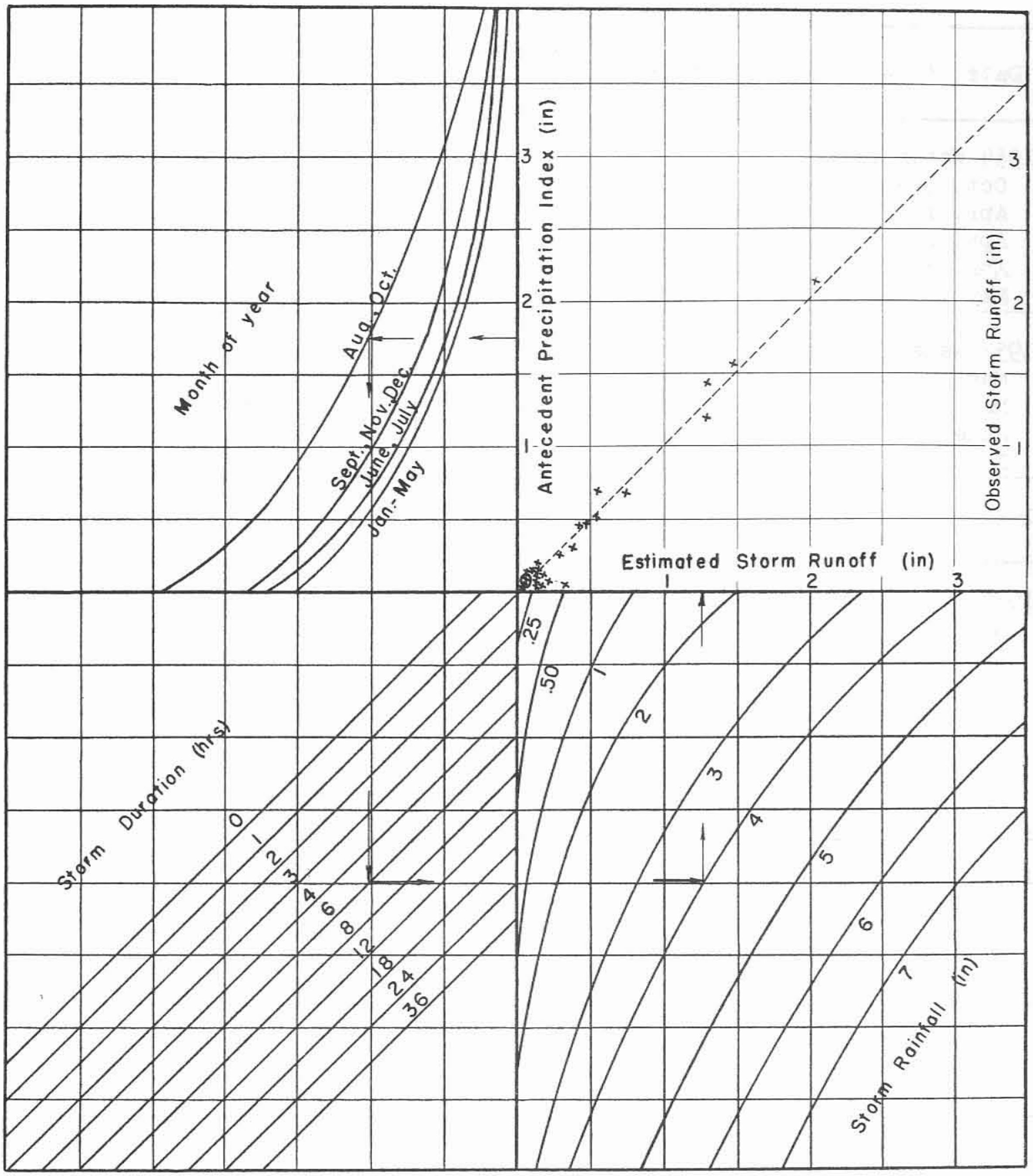

Figure 16

Coaxial Rainfall-Runoff Relation for Mukewater Creek Study Area, Including Plot of Estimated Versus Observed Storm Runoff for 30 Storms Used for Correlation

U. S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Table 5.--Storm parameters used in constructing coaxial rainfall-runoff relation

Date of storm	API* (inches)	Duration of storm (hours)	Storm WMR† (inches)	Storm runoff (inches)
1954 Water Year:				
Oct. 3-4	0.21	12.5	3.94	0.49
Apr. 12	.01	1.0	1.17	.11
Apr. 27	.39	.50	.63	.07
Apr. 30	.52	2.0	.57	.08
May 11	.38	4.0	1.12	.16
1955 Water Year:				
May 10-11	.14	1.5	2.55	.70
May 11	2.69	.25	.58	.26
June 4	.11	1.0	.98	.17
Sept. 22	.03	6.0	2.82	.46
1956 Water Year:				
Apr. 30-May 1	.95	5.0	4.85	2.16
1957 Water Year:				
Mar. 20	.18	.50	1.02	.08
Apr. 18-19	.06	4.0	1.84	.20
Apr. 22-23	.97	4.0	1.18	.21
Apr. 26	1.19	4.0	3.19	1.45
May 11	.81	1.25	1.51	.71
May 23	.87	1.25	1.11	.32
June 1	.50	.50	.63	.09
June 12	.21	.40	.96	.05
1958 Water Year:				
Feb. 22	.70	14.0	1.58	.15
May 13	.22	3.0	1.22	.04
June 21	.10	1.5	2.00	.06
Aug. 23-24	.04	5.0	2.33	.10
1959 Water Year:				
June 3-4	2.71	2.0	2.42	1.20
July 21	2.24	5.0	3.36	1.60
1960 Water Year:				
Oct. 3-4	.67	24.0	4.18	.52
Dec. 31	.07	5.0	1.08	.03
Jan. 4-5	.47	14.0	1.31	.16
Jan. 13	.62	2.5	.86	.13
Feb. 2-3	.02	2.5	.89	.04

*Antecedent precipitation index
†Weighted-mean rainfall

a watershed along with a 6-inch storm on the other one-half of a watershed usually will produce a different runoff than a 4-inch storm over the entire watershed, although each storm averages 4 inches.

To evaluate the effects on runoff of areal distribution of rainfall, the study area was divided into six subareas as shown on Figure 3. Four of the subareas coincide approximately with the drainage areas of floodwater-retarding structures as originally proposed. Subareas 5 and 6 will be the uncontrolled portion of the study area after it is developed. Plans for site 10A were revised after computations for this report were complete. According to revised plans, approximately 2.6 square miles of subarea 2 will also be uncontrolled. The coaxial rainfall-runoff relation as previously developed using uniform storms was assumed to be applicable to smaller watersheds.

An arithmetic average rainfall was computed for each subarea for all storms which showed as much as 0.4 inch rainfall at any one of the subareas. Duration of the storm was determined using the nearest recording gage or gages. Rain gages which appeared to be most representative of rainfall on each subarea were selected.

The API for each subarea was assumed to be the same as that for the entire watershed. Table 6 shows computations of API for all storms occurring during the 7 water years 1954-60. Using these data and Figure 16, storm runoff was estimated for each subarea for each qualifying storm during the 7-year period. Estimated total storm runoff was computed by summing the contribution from each subarea. Table 7 summarizes the runoff estimates from each of the six subareas and the estimated total runoff for the water years 1954-60.

To check the accuracy of the estimated runoff, monthly and annual runoff values were compiled from Table 7 and compared to runoff as observed at the stream-gaging station. Table 8 shows this comparison for the 7-year period studied. Differences are computed using observed runoff as the base. The monthly and annual values of observed runoff in Table 8 do not necessarily coincide with the comparable totals as published in the annual U.S. Geological Survey Water-Supply Papers. The reason for this is that at times hydrographs generated by a storm in one month end in the next month; therefore, runoff totals are separated in this report, based on the month in which runoff was generated. This procedure provides a more meaningful comparison of concurrent runoff.

Runoff Estimates Neglecting Distribution

Because it seems that areal distribution of rainfall would be an important factor in the rainfall-runoff relation, a study was made to determine whether the inclusion of the areal distribution variable would produce results which were significantly more accurate than estimated runoff obtained by neglecting this variable. If the areal distribution is neglected, runoff may be estimated by using weighted-mean rainfall for the entire study area and an average duration based on all recording rain gages within the study area. Runoff was estimated from Figure 16 for the entire period of record following this procedure.

Storms used in this study were the same as those used for the estimates made considering rainfall distribution on six subareas. Table 9 shows the estimated runoff from each storm neglecting rainfall distribution. Table 10

Table 6.--Antecedent precipitation index (API) computations

Date of storm	WMR (inches)	t (days)	K^t	API (inches)	API + WMR (inches)
1953 Calendar Year					
Oct. 3	0.20	-	-	0.01	0.21
Oct. 3-4	3.94	0	1.000	.21	4.15
Oct. 23	.12	19	.014	.06	.18
Oct. 29	.35	6	.262	.05	.40
Nov. 4	.14	7	.210	.08	.22
Nov. 19	.18	15	.035	.01	.19
Dec. 2	.09	13	.055	.01	.10
Dec. 22	.01	20	.012	0	.01
Dec. 27	.01	5	.328	0	.01
1954 Calendar Year					
Jan. 13	.01	17	.023	0	.01
Jan. 13-14	.08	0	1.000	.01	.09
Jan. 14-15	.15	0	1.000	.09	.24
Jan. 21	.07	6	.262	.06	.13
Feb. 2	.11	12	.069	.01	.12
Feb. 19	.10	17	.023	0	.10
Mar. 4	.04	13	.055	.01	.05
Mar. 5	.05	1	.800	.04	.09
Mar. 24	.90	19	.014	0	.90
Apr. 12	1.17	19	.014	.01	1.18
Apr. 15	.08	3	.512	.60	.68
Apr. 22-23	.81	7	.210	.14	.95
Apr. 27	.63	4	.410	.39	1.02
Apr. 30	.57	3	.512	.52	1.09
May 1	.16	1	.800	.87	1.03
May 6	.17	5	.328	.34	.51
May 10	.26	4	.410	.21	.47
May 11	1.12	1	.800	.38	1.50
May 18	.10	7	.210	.32	.42
May 23	.17	5	.328	.14	.31
May 24	.18	1	.800	.25	.43
June 7	.60	14	.044	.02	.62
June 22	.45	15	.035	.02	.47
June 26	.06	4	.410	.19	.25
July 6	.07	10	.107	.03	.10
July 31	1.11	25	.004	0	1.11
Aug. 1	.07	1	.800	.89	.96
Aug. 19	.10	18	.018	.02	.12
Aug. 31	.48	12	.069	.01	.49
Sept. 4	.02	4	.410	.20	.22
Sept. 20	.01	16	.028	.01	.02
Sept. 29	.13	9	.134	0	.13
Sept. 30	.06	1	.800	.10	.16
Oct. 5	.90	5	.328	.05	.95
Oct. 27	.82	22	.007	.01	.83
Nov. 3	.12	7	.210	.17	.29
Nov. 9	.13	6	.262	.08	.21
Nov. 14	.91	5	.328	.07	.98
Dec. 11	.06	27	.002	0	.06
Dec. 28	.23	17	.023	0	.23
1955 Calendar Year					
Jan. 5	.03	8	.168	.04	.07
Jan. 9	.48	4	.410	.03	.51
Jan. 14	.07	5	.328	.17	.24
Jan. 14	.05	0	1.000	.24	.29
Jan. 15	.09	1	.800	.23	.32
Jan. 17	.08	2	.640	.20	.28
Feb. 3	.08	17	.023	.01	.09
Feb. 4	.78	1	.800	.07	.85
Feb. 19	.01	15	.035	.03	.04
Feb. 27	.01	8	.168	.01	.02
Mar. 13	.32	14	.044	0	.32
Mar. 18	.26	5	.328	.10	.36
Mar. 19	.11	1	.800	.29	.40
Apr. 5	.05	17	.023	.01	.06
Apr. 9	.16	4	.410	.02	.18
Apr. 11	.32	2	.640	.12	.44
Apr. 20	.17	9	.134	.06	.23
May 7	.07	17	.023	.01	.08
May 8-9	.11	1	.800	.06	.17
May 10-11	2.55	1	.800	.14	2.69
May 11	.58	0	1.000	2.69	3.27
May 16-17	.54	5	.328	1.07	1.61
May 17	1.94	0	1.000	1.61	3.55
May 18-19	.69	1	.800	2.84	3.53
May 26	.19	7	.210	.74	.93
June 4	.98	9	.134	.11	1.09
June 5	.08	1	.800	.87	.95
June 6	.76	1	.800	.76	1.52
June 8	.67	2	.640	.97	1.64
June 9	.16	1	.800	1.31	1.47
June 14-15	1.16	5	.328	.48	1.64
1955 Calendar Year.--Continued					
June 15	0.14	0	1.000	1.64	1.78
June 29	.02	14	.044	.08	.10
July 12	.06	13	.055	.01	.07
July 15	.31	3	.512	.04	.35
July 16-17	2.16	1	.800	.28	2.44
July 17-18	1.44	0	1.000	2.44	3.88
July 18	.14	0	1.000	3.88	4.02
July 23	.04	5	.328	1.32	1.36
Aug. 9	.14	17	.023	.03	.17
Aug. 10	.05	1	.800	.14	.19
Aug. 11	.03	1	.800	.15	.18
Aug. 12	.07	1	.800	.14	.21
Aug. 18	.35	6	.262	.06	.41
Aug. 21	.15	3	.512	.21	.36
Aug. 28	.13	7	.210	.08	.21
Aug. 30	.71	2	.640	.13	.84
Sept. 10-11	.28	11	.086	.07	.35
Sept. 22	2.82	11	.086	.03	2.85
Sept. 24	.42	2	.640	1.82	2.24
Oct. 5	.03	11	.086	.19	.22
Oct. 6	.01	1	.800	.18	.19
Nov. 30	.51	55	0	0	.51
1956 Calendar Year					
Jan. 17	.88	48	0	0	.88
Jan. 21	.56	4	.410	.36	.92
Feb. 1	.06	11	.086	.08	.14
Feb. 2	.10	1	.800	.11	.21
Feb. 8	.29	6	.262	.06	.35
Feb. 9	.16	1	.800	.28	.44
Feb. 16	.03	7	.210	.09	.12
Mar. 12	.04	25	.004	0	.04
Mar. 21	.02	9	.134	.01	.03
Apr. 5	.23	15	.035	0	.23
Apr. 20	.17	15	.035	.01	.18
Apr. 21	.48	1	.800	.14	.62
Apr. 29	.25	8	.168	.10	.35
Apr. 30	.67	1	.800	.28	.95
Apr. 30-May 1	4.85	0	1.000	.95	5.80
May 1	.09	0	1.000	5.80	5.89
May 14	.38	13	.055	.32	.70
May 23-24	.82	9	.134	.09	.91
June 9	.16	16	.028	.03	.19
June 19	.01	10	.107	.02	.03
July 2	.05	13	.055	0	.05
July 4	.04	2	.640	.03	.07
Aug. 19	.69	46	0	0	.69
Aug. 28	.67	9	.134	.09	.76
Sept. 6	.45	9	.134	.10	.55
Sept. 26	.14	20	.012	.01	.15
Oct. 15	.69	19	.014	.01	.70
Oct. 18	.96	3	.512	.36	1.32
Oct. 30	.77	12	.069	.09	.86
Nov. 2	.31	3	.512	.44	.75
Nov. 4	.55	2	.640	.48	1.03
Dec. 6	.20	32	.001	0	.20
Dec. 18-19	1.06	12	.069	.01	1.07
1957 Calendar Year					
Jan. 3	.12	15	.035	.04	.16
Jan. 23	.11	20	.012	0	.11
Jan. 25	.11	2	.640	.07	.18
Jan. 30	.04	5	.328	.06	.10
Jan. 31	.30	1	.800	.08	.38
Feb. 13	.06	13	.055	.02	.08
Feb. 16	.46	3	.512	.04	.50
Feb. 17	.30	1	.800	.40	.70
Feb. 19	.07	2	.640	.45	.52
Feb. 22	.15	3	.512	.27	.42
Mar. 10	.51	16	.028	.01	.52
Mar. 17	.01	7	.210	.11	.12
Mar. 20	.12	3	.512	.06	.18
Mar. 20	1.02	0	1.000	.18	1.20
Mar. 31	.21	11	.086	.10	.31
Apr. 3	.33	3	.512	.16	.49
Apr. 12-13	.10	9	.134	.07	.17
Apr. 18-19	1.84	5	.328	.06	1.90
Apr. 22-23	1.18	3	.512	.97	2.15
Apr. 24	.14	1	.800	1.72	1.86
Apr. 26	3.19	2	.640	1.19	4.38
Apr. 28-29	.39	2	.640	2.80	3.19
Apr. 29	.09	0	1.000	3.19	3.28
Apr. 30	.20	1	.800	2.62	2.82
May 3	.14	3	.512	1.44	1.58

Table 6.--Antecedent precipitation index (API) computations--Continued

Date of storm	WMR (inches)	t (days)	K^t	API (inches)	API + WMR (inches)
1957 Calendar Year.--Continued					
May 4	0.41	1	0.800	1.26	1.67
May 9	.71	5	.328	.55	1.26
May 11	1.51	2	.640	.81	2.32
May 12	.43	1	.800	1.86	2.29
May 13	.79	1	.800	1.83	2.62
May 17	1.31	4	.410	1.07	2.38
May 18	.76	1	.800	1.90	2.66
May 23	1.11	5	.328	.87	1.98
May 25	.07	2	.640	1.27	1.34
May 26	.11	1	.800	1.07	1.18
May 31	.23	5	.328	.39	.62
June 1	.63	1	.800	.50	1.13
June 1	.13	0	1.000	1.13	1.26
June 2	.07	1	.800	1.01	1.08
June 5	.43	3	.512	.55	.98
June 12	.96	7	.210	.21	1.17
July 9	.18	27	.002	0	.18
July 21	.14	12	.069	.01	.15
July 22	.12	1	.800	.12	.24
July 23	.60	1	.800	.19	.79
July 26	.08	3	.512	.40	.48
Aug. 2	.06	7	.210	.10	.16
Aug. 5	.46	3	.512	.08	.54
Sept. 3	.36	29	.002	0	.36
Sept. 7	.13	4	.410	.15	.28
Sept. 11	.73	4	.410	.11	.84
Sept. 21	.31	10	.107	.09	.40
Sept. 25	.04	4	.410	.16	.20
Oct. 8	.04	13	.055	.01	.05
Oct. 13	1.51	5	.328	.02	1.53
Oct. 14	1.07	1	.800	1.22	2.29
Oct. 15	.49	1	.800	1.83	2.32
Oct. 21-22	.27	6	.262	.61	.88
Oct. 22	.12	0	1.000	.88	1.00
Nov. 2	.08	11	.086	.09	.17
Nov. 3	.30	1	.800	.14	.44
Nov. 3-4	.13	0	1.000	.44	.57
Nov. 5	.76	1	.800	.46	1.22
Nov. 6	.04	1	.800	.98	1.02
Nov. 7	.09	1	.800	.82	.91
Nov. 8	.02	1	.800	.73	.75
Nov. 9	.32	1	.800	.60	.92
Nov. 10-11	.26	1	.800	.74	1.00
Nov. 18	.07	7	.210	.21	.28
Nov. 21	.11	3	.512	.14	.25
Nov. 23	.06	2	.640	.16	.22
Nov. 24	.97	1	.800	.18	1.15
Dec. 6	.32	12	.069	.08	.40
Dec. 24-25	.95	18	.018	.01	.96
1958 Calendar Year					
Jan. 4-5	.67	10	.107	.10	.77
Jan. 12	.23	7	.210	.16	.39
Jan. 18	.11	6	.262	.10	.21
Jan. 19	.27	1	.800	.17	.44
Jan. 22-23	.76	3	.512	.23	.99
Feb. 5	.01	13	.055	.05	.06
Feb. 9-12	.09	6	.262	.02	.11
Feb. 14	.01	3	.512	.06	.07
Feb. 20	.15	6	.262	.02	.17
Feb. 21	.14	1	.800	.14	.28
Feb. 21	.59	0	1.000	.28	.87
Feb. 22	1.58	1	.800	.70	2.28
Mar. 1	.31	7	.210	.48	.79
Mar. 4	.17	3	.512	.40	.57
Mar. 5	.12	1	.800	.46	.58
Mar. 6	.67	1	.800	.46	1.13
Mar. 8	.16	2	.640	.72	.88
Mar. 12	.48	4	.410	.36	.84
Mar. 18	.06	6	.262	.22	.28
Mar. 22	.30	4	.410	.11	.41
Mar. 25	.20	3	.512	.21	.41
Mar. 28	.02	3	.512	.21	.23
Apr. 8	.28	11	.086	.02	.30
Apr. 13	1.07	5	.328	.10	1.17
Apr. 17	.23	4	.410	.48	.71
Apr. 18	.11	1	.800	.57	.68
Apr. 20	.81	2	.640	.44	1.25
Apr. 25-29	.05	7	.210	.26	.31
Apr. 30	.36	3	.512	.16	.52
May 2	.23	3	.512	.27	.50
May 2	.75	0	1.000	.50	1.25
May 9	.09	7	.210	.26	.35
May 11	.12	2	.640	.22	.34

Date of storm	WMR (inches)	t (days)	K^t	API (inches)	API + WMR (inches)
1958 Calendar Year.--Continued					
May 13	1.22	2	0.640	0.22	1.44
May 14	.11	1	.800	1.15	1.26
May 16	.20	2	.640	.81	1.01
June 8	.05	23	.006	.01	.06
June 16	.27	8	.168	.01	.28
June 21	2.00	5	.328	.10	2.10
July 6	.12	15	.035	.07	.19
July 20	.10	14	.044	.01	.11
July 22	.38	2	.640	.07	.45
Aug. 10	.07	19	.014	.01	.08
Aug. 17	.13	7	.210	.02	.15
Aug. 23-24	2.33	6	.262	.04	2.37
Sept. 6	.43	13	.055	.13	.56
Sept. 7	.26	1	.800	.45	.71
Sept. 15-16	.66	8	.168	.12	.78
Sept. 16	.11	0	1.000	.78	.89
Sept. 19	.53	3	.512	.46	.99
Sept. 25	.22	6	.262	.26	.48
Sept. 26	.02	1	.800	.38	.40
Oct. 3	.37	7	.210	.08	.45
Oct. 12	.31	9	.134	.06	.37
Oct. 14	.23	2	.640	.24	.47
Oct. 21	.01	7	.210	.10	.11
Oct. 25	.13	4	.410	.05	.18
Oct. 28-29	.35	3	.512	.09	.44
Nov. 14	.84	17	.023	.01	.85
Nov. 17	.14	3	.512	.44	.58
Nov. 27	.15	10	.107	.06	.21
Dec. 1	.14	4	.410	.09	.23
Dec. 29	.26	28	.002	0	.26
1959 Calendar Year					
Feb. 1-2	.27	34	.001	0	.27
Feb. 13	.26	11	.086	.02	.28
Feb. 19	.10	6	.262	.07	.17
Feb. 20	.23	1	.800	.14	.37
Mar. 4	.22	12	.069	.03	.25
Mar. 28	.03	24	.005	0	.03
Apr. 8	.39	11	.086	0	.39
Apr. 10	.72	2	.640	.25	.97
Apr. 17	.09	7	.210	.20	.29
Apr. 18	.34	1	.800	.23	.57
Apr. 29	.17	11	.086	.05	.22
May 1-2	.35	2	.640	.14	.49
May 5	.26	3	.512	.25	.51
May 10	.34	5	.328	.17	.51
May 15	1.52	5	.328	.17	1.69
May 16	.07	1	.800	1.35	1.42
May 22	.74	6	.262	.37	1.11
May 25	.03	3	.512	.57	.60
June 1	1.70	7	.210	.13	1.83
June 2	.49	1	.800	1.46	1.95
June 3	1.15	1	.800	1.56	2.71
June 3-4	2.42	0	1.000	2.71	5.13
June 5	.08	1	.800	4.10	4.18
June 8	.18	3	.512	2.14	2.32
June 22-23	.03	14	.044	.10	.13
June 23-24	.61	0	1.000	.13	.74
June 25-26	2.54	1	.800	.59	3.13
July 2	.26	6	.262	.82	1.08
July 9	.09	7	.210	.23	.32
July 15	.23	6	.262	.08	.31
July 18	.37	3	.512	.16	.53
July 19	1.85	1	.800	.42	2.27
July 20	.98	1	.800	1.82	2.80
July 21	3.36	1	.800	2.24	5.60
Aug. 8	.46	18	.018	.10	.56
Aug. 24	.11	16	.028	.02	.13
Aug. 28	.05	4	.410	.05	.10
Aug. 30	.07	2	.640	.06	.13
Aug. 31	.73	1	.800	.10	.83
Sept. 8	trace	8	.168	.14	.14
Sept. 10	.18	2	.640	.09	.27
Sept. 24	.09	14	.044	.01	.10
Sept. 29	.05	5	.328	.03	.08
Sept. 30	1.24	1	.800	.06	1.30
Oct. 3-4	4.18	3	.512	.67	4.85
Oct. 13	.89	9	.134	.65	1.54
Nov. 1	.19	19	.014	.02	.21
Nov. 3	.57	2	.640	.13	.70
Nov. 14	.08	11	.086	.06	.14
Nov. 15	.19	1	.800	.11	.30
Dec. 11	.17	26	.003	0	.17
Dec. 14-15	.64	3	.512	.09	.73

Table 6.--Antecedent precipitation index (API) computations--Continued

Date of storm	WMR (inches)	t (days)	K^t	API (inches)	API + WMR (inches)
1959 Calendar Year.--Continued					
Dec. 16	0.61	1	0.800	0.58	1.19
Dec. 16-17	.39	0	1.000	1.19	1.58
Dec. 31	1.08	14	.044	.07	1.15
1960 Calendar Year					
Jan. 4-5	1.31	4	.410	.47	1.78
Jan. 12	.41	7	.210	.37	.78
Jan. 13	.86	1	.800	.62	1.48
Jan. 14	.04	1	.800	1.18	1.22
Feb. 2-3	.89	19	.014	.02	.91
Feb. 23	.26	20	.012	.01	.27
Feb. 28-29	.04	5	.328	.09	.13
Mar. 13	trace	13	.055	.01	.01
Mar. 24	.37	11	.086	0	.37
Apr. 13	.05	20	.012	0	.05
Apr. 24	.82	7	.210	.01	.83
Apr. 25	.69	1	.800	.66	1.35
Apr. 26	.39	1	.800	1.08	1.47
Apr. 27	.27	1	.800	1.18	1.45
Apr. 29	.56	2	.640	.93	1.49
May 4	.03	5	.328	.49	.52
May 17	.09	13	.055	.03	.12
May 18	.35	1	.800	.10	.45
May 19	.33	1	.800	.36	.69

Date of storm	WMR (inches)	t (days)	K^t	API (inches)	API + WMR (inches)
1960 Calendar Year.--Continued					
May 27	0.48	8	0.168	0.12	0.60
May 30	.32	3	.512	.31	.63
June 7	.11	8	.168	.11	.22
June 11	.08	4	.410	.09	.17
June 15	.14	4	.410	.07	.21
June 25	.25	10	.107	.02	.27
July 15	.01	20	.012	0	.01
July 16	.57	1	.800	.01	.58
July 18	.11	2	.640	.37	.48
July 19	.32	1	.800	.38	.70
July 20	.28	1	.800	.56	.84
July 24	.15	4	.410	.34	.49
July 26	.20	2	.640	.31	.51
Aug. 9	1.22	14	.044	.02	1.24
Aug. 10	.71	1	.800	.99	1.70
Aug. 11	.08	1	.800	1.36	1.44
Aug. 15	.31	4	.410	.59	.90
Aug. 20	.08	5	.328	.30	.38
Aug. 21	.14	1	.800	.30	.44
Aug. 30	.15	9	.134	.06	.21
Sept. 23	1.08	24	.005	0	1.08
Sept. 24	.54	1	.800	.86	1.40
Sept. 25-26	.13	1	.800	1.12	1.25

Table 7.--Runoff estimates for study area using six subareas for all storms where average rainfall on any subarea exceeded 0.40 inch

Date of storm	API* (in)	Subarea 1 Avg. rain (in)	Subarea 1 Duration (hr)	Subarea 1 Estimated runoff (in)	Subarea 1 Estimated runoff (ac-ft)	Subarea 2 Avg. rain (in)	Subarea 2 Duration (hr)	Subarea 2 Estimated runoff (in)	Subarea 2 Estimated runoff (ac-ft)	Subarea 3 Avg. rain (in)	Subarea 3 Duration (hr)	Subarea 3 Estimated runoff (in)	Subarea 3 Estimated runoff (ac-ft)	Subarea 4 Avg. rain (in)	Subarea 4 Duration (hr)	Subarea 4 Estimated runoff (in)	Subarea 4 Estimated runoff (ac-ft)	Subarea 5 Avg. rain (in)	Subarea 5 Duration (hr)	Subarea 5 Estimated runoff (in)	Subarea 5 Estimated runoff (ac-ft)	Subarea 6 Avg. rain (in)	Subarea 6 Duration (hr)	Subarea 6 Estimated runoff (in)	Subarea 6 Estimated runoff (ac-ft)	Total (ac-ft)
1954 WATER YEAR																										
1953																										
Oct. 3-4	0.21	3.58	12.5	0.36	187	3.75	12.5	0.43	365	3.48	12.5	0.35	75	3.92	12.5	0.46	191	4.22	12.5	0.61	481	4.10	12.5	0.57	539	1,840
29	.05	.28	2.0	0	0	.33	2.0	0	0	.28	2.0	0	0	.28	2.0	0	0	.40	2.0	0	0	.43	2.0	0	0	0
1954																										
Mar. 24	0	.46	.75	0	0	.82	1.0	.11	93	.69	1.0	.05	11	.67	1.0	.05	21	.94	1.0	.14	110	1.21	1.0	.25	236	471
Apr. 12	.01	1.29	1.5	.20	104	1.10	1.0	.18	153	1.12	.50	.21	45	1.55	.50	.31	129	1.23	.50	.25	197	.97	.50	.15	142	770
22-23	.14	1.48	7.0	.05	26	.69	7.0	0	0	.58	7.0	0	0	.70	7.0	0	0	.57	7.0	0	0	.69	7.0	0	0	26
27	.39	.67	.50	.11	57	.63	.50	.10	85	.59	.50	.09	19	.63	.50	.10	42	.53	.50	.06	47	.64	.50	.10	95	345
30	.52	.62	2.0	.06	31	.69	2.0	.08	68	.68	2.0	.08	17	.57	2.0	.05	21	.66	2.0	.07	55	.40	2.0	0	0	192
May 6	.34	.51	.25	.06	31	.16	.25	0	0	.07	.25	0	0	.05	.25	0	0	.08	.25	0	0	.09	.25	0	0	31
11	.38	.84	4.0	.05	26	1.03	4.0	.09	76	1.14	4.0	.11	24	1.29	4.0	.13	54	1.32	4.0	.14	110	1.20	4.0	.12	114	404
June 7	.02	1.01	2.0	.06	31	.66	2.0	0	0	.69	2.0	0	0	.51	2.0	0	0	.47	2.0	0	0	.53	2.0	0	0	31
22	.02	.06	.50	0	0	.34	.75	0	0	.51	.75	0	0	.97	.50	.10	42	.86	.75	.08	63	.30	1.0	0	0	105
July 31	0	.65	5.0	0	0	.89	5.0	0	0	1.20	4.5	.02	4	1.76	4.0	.06	25	1.41	5.0	.04	32	1.05	5.0	.01	9	70
Aug. 31	.01	.42	1.25	0	0	.26	.50	0	0	.65	1.25	0	0	.99	2.5	0	0	.69	2.5	0	0	.34	2.5	0	0	0
1955 WATER YEAR																										
1954																										
Oct. 5	.05	.96	2.0	0	0	.88	2.0	0	0	1.21	2.0	.02	4	1.12	2.0	.01	4	.87	2.0	0	0	.80	2.0	0	0	8
27	.01	1.18	4.0	0	0	.83	4.0	0	0	.91	3.5	0	0	.83	3.0	0	0	.69	3.5	0	0	.70	4.0	0	0	0
Nov. 14	.07	1.15	6.5	.01	5	.87	6.5	0	0	1.21	6.5	.02	4	1.12	6.5	.01	4	.80	6.5	0	0	.73	6.5	0	0	13
1955																										
Jan. 9	.03	.55	3.0	0	0	.48	3.0	0	0	.52	3.0	0	0	.54	3.0	0	0	.45	3.0	0	0	.40	3.0	0	0	0
Feb. 4	.07	.85	2.5	.06	31	.73	2.25	.02	17	.69	2.5	.01	2	.79	2.5	.04	17	.77	2.25	.04	32	.74	2.25	.03	28	127
Mar 13	0	.56	.50	.05	26	.31	.75	0	0	.41	.75	0	0	.51	.75	.01	4	.34	.75	0	0	.02	.75	0	0	30
18	.10	.03	.25	0	0	.21	.25	0	0	.14	.25	0	0	.19	.25	0	0	.21	.25	0	0	.47	.25	.02	19	19
Apr. 11	.12	.81	1.0	.08	42	.22	.75	0	0	.43	.50	0	0	.52	.25	.04	17	.24	.25	0	0	.05	.50	0	0	59
May 10-11	.14	1.33	2.0	.21	692	2.66	1.5	.83	704	2.95	1.75	1.05	226	3.13	2.0	1.12	465	2.62	1.75	.81	639	2.59	1.5	.84	795	3,520
11	2.69	.41	.25	.17	88	.53	.25	.30	254	.46	.25	.21	45	.61	.25	.36	149	.58	.25	.33	260	.70	.25	.42	397	1,190
16-17	1.07	.91	.25	.38	198	.56	.25	.18	153	.60	.25	.20	43	.56	.25	.18	75	.47	.25	.10	79	.31	.25	.01	9	557
17	1.61	1.96	7.0	.27	140	2.14	7.0	.39	331	2.01	7.0	.30	64	1.94	7.0	.27	112	1.87	7.0	.25	197	1.96	7.0	.25	236	1,080
18-19	2.84	.74	1.5	.37	192	.77	1.5	.38	322	.70	1.5	.36	77	.66	1.5	.33	137	.70	1.5	.36	284	.63	1.5	.31	293	1,300
June 4	.11	1.12	.75	.19	99	.82	1.0	.13	110	1.04	1.0	.16	34	1.40	1.0	.24	100	1.03	1.0	.16	126	.77	.75	.08	76	545
6	.76	.78	.25	.23	120	1.04	.25	.39	331	.78	.25	.20	43	.22	.25	0	0	.58	.25	.14	110	.88	.25	.27	255	859
8	.97	.86	2.0	.20	104	.62	2.0	.12	102	.78	2.0	.16	34	.95	2.0	.24	100	.74	2.0	.15	118	.46	2.0	.01	9	467
14-15	.48	1.47	.25	.45	234	1.18	.25	.35	297	1.45	.25	.45	97	1.62	.25	.50	208	1.29	.25	.40	316	.77	.25	.19	180	1,330
July 15	.04	.24	1.0	0	0	.49	.50	0	0	.42	1.5	0	0	.12	2.0	0	0	.29	1.0	0	0	.44	.25	0	0	0
16-17	.28	1.81	5.0	.16	83	2.56	5.0	.43	365	2.62	5.0	.44	95	1.95	5.0	.17	71	2.34	5.0	.38	300	2.20	5.0	.33	312	1,230
17-18	2.44	1.43	3.0	.54	281	1.28	3.0	.46	390	1.30	3.0	.46	99	1.34	3.0	.48	199	1.52	2.5	.57	450	1.61	2.0	.60	568	1,990
Aug. 9	.03	.14	.25	0	0	.29	.25	0	0	.47	.25	0	0	.20	.25	0	0	.07	.25	0	0	.01	.25	0	0	0
18	.06	.23	.25	0	0	.47	.25	0	0	.48	.25	0	0	.44	.25	0	0	.25	.25	0	0	.34	.25	0	0	0
30	.13	.55	1.0	0	0	.26	1.0	0	0	.62	1.0	0	0	.79	1.0	.01	4	1.21	1.0	.08	63	1.06	1.0	.07	66	133
Sept. 10-11	.07	.42	.50	0	0	.49	.50	0	0	.48	.50	0	0	.30	.50	0	0	.23	.50	0	0	.11	.50	0	0	0
22	.03	2.67	6.0	.32	166	2.88	6.0	.41	348	3.07	6.0	.53	114	2.94	6.0	.45	187	2.70	6.0	.33	260	2.96	6.0	.46	435	1,510
24	1.82	.45	.50	.10	52	.41	.50	.05	42	.48	.50	.12	26	.33	.50	.01	4	.46	.50	.10	79	.46	.50	.10	95	298

*Antecedent precipitation index

Table 7.--Runoff estimates for study area using six subareas for all storms where average rainfall on any subarea exceeded 0.40 inch--Continued

Date of storm	API* (in)	Subarea 1 Avg. rain (in)	Subarea 1 Duration (hr)	Subarea 1 Estimated runoff (in)	Subarea 1 Estimated runoff (ac-ft)	Subarea 2 Avg. rain (in)	Subarea 2 Duration (hr)	Subarea 2 Estimated runoff (in)	Subarea 2 Estimated runoff (ac-ft)	Subarea 3 Avg. rain (in)	Subarea 3 Duration (hr)	Subarea 3 Estimated runoff (in)	Subarea 3 Estimated runoff (ac-ft)	Subarea 4 Avg. rain (in)	Subarea 4 Duration (hr)	Subarea 4 Estimated runoff (in)	Subarea 4 Estimated runoff (ac-ft)	Subarea 5 Avg. rain (in)	Subarea 5 Duration (hr)	Subarea 5 Estimated runoff (in)	Subarea 5 Estimated runoff (ac-ft)	Subarea 6 Avg. rain (in)	Subarea 6 Duration (hr)	Subarea 6 Estimated runoff (in)	Subarea 6 Estimated runoff (ac-ft)	Total (ac-ft)
1956 WATER YEAR																										
1955																										
Nov. 30	0	0.49	11.0	0	0	0.49	11.0	0	0	0.56	11.0	0	0	0.56	11.0	0	0	0.49	11.0	0	0	0.50	11.0	0	0	0
1956																										
Jan. 17	0	1.10	8.0	0	0	.86	8.5	0	0	.93	8.5	0	0	.86	9.0	0	0	.85	8.5	0	0	.83	8.0	0	0	0
21	.36	.49	2.5	0	0	.49	4.0	0	0	.54	3.5	0	0	.56	5.0	0	0	.69	5.5	0	0	.60	6.0	0	0	0
Apr. 5	0	.47	2.0	0	0	.25	2.0	0	0	.40	2.0	0	0	.32	2.0	0	0	.13	2.0	0	0	.09	2.0	0	0	0
21	.14	.43	6.0	0	0	.46	6.0	0	0	.46	6.0	0	0	.49	6.0	0	0	.54	6.0	0	0	.51	6.0	0	0	0
29	.10	.03	-	0	0	.21	1.0	0	0	.03	-	0	0	.03	-	0	0	.29	1.0	0	0	.52	1.0	.01	9	9
30	.28	.55	1.0	.05	26	.73	.50	.15	127	.66	.50	.12	26	.61	.50	.10	42	.77	.50	.16	126	.70	.50	.15	142	489
Apr. 30- May 1	.95	6.74	4.0	3.28	1,706	4.35	5.0	1.75	1,484	4.97	5.0	2.14	460	5.79	4.0	2.67	1,108	5.24	5.0	2.31	1,823	3.31	6.0	1.10	1,041	7,620
14	.32	.71	.75	.11	57	.37	.25	0	0	.39	.50	0	0	.38	.25	0	0	.35	.25	0	0	.26	.25	0	0	57
23-24	.09	.71	12.0	0	0	.88	12.0	0	0	.80	12.0	0	0	.49	12.0	0	0	.77	12.0	0	0	1.03	12.0	0	0	0
June 9	.03	0	-	0	0	.08	-	0	0	0	-	0	0	.05	-	0	0	.43	3	0	0	.32	3	0	0	0
Aug. 19	0	.68	.75	0	0	.75	.50	0	0	.34	.50	0	0	.58	.50	0	0	1.10	.50	.04	32	.70	.50	0	0	32
28	.09	.23	3.5	0	0	.64	5.0	0	0	.71	5.0	0	0	.94	5.0	0	0	.92	5.0	0	0	.69	5.0	0	0	0
Sept. 6	.10	.16	1.5	0	0	.45	1.5	0	0	.20	1.5	0	0	.25	1.5	0	0	.53	1.5	0	0	.72	1.5	.03	28	28
1957 WATER YEAR																										
1956																										
Oct. 15	.01	.77	2.5	0	0	.67	2.5	0	0	.73	2.5	0	0	.74	2.5	0	0	.66	2.5	0	0	.70	2.5	0	0	0
18	.36	.84	.50	.05	26	1.02	.50	.11	93	.93	.50	.07	15	.79	.50	.02	8	1.03	.50	.11	87	1.03	.50	.11	104	333
30	.09	.63	2.0	0	0	.81	2.0	0	0	.66	2.0	0	0	.99	2.0	.01	4	.94	2.0	.01	8	.71	2.0	0	0	12
Nov. 2	.44	.15	1.0	0	0	.24	1.0	0	0	.22	1.25	0	0	.35	.50	0	0	.34	1.25	0	0	.43	2.0	0	0	0
4	.48	.79	1.5	.10	52	.67	2.0	.04	34	.76	2.0	.07	15	.55	2.5	0	0	.49	2.5	0	0	.36	3.0	0	0	101
Dec. 18-19	.01	.98	36.0	0	0	.97	36.0	0	0	1.02	36.0	0	0	1.12	36.0	0	0	1.11	36.0	0	0	1.08	36.0	0	0	0
1957																										
Feb. 16	.04	1.53	8.0	0	0	.48	8.0	0	0	.56	8.0	0	0	.60	8.0	0	0	.47	8.0	0	0	.36	8.0	0	0	0
Mar. 10	.01	.42	1.5	0	0	.49	1.5	0	0	.40	1.5	0	0	.45	1.5	0	0	.52	1.5	0	0	.60	1.5	0	0	0
20	.18	.77	.50	.14	73	.98	.50	.22	187	.74	.50	.14	30	.74	.50	.14	58	1.13	.50	.28	221	1.32	.50	.34	322	891
Apr. 3	.16	.60	1.0	.05	26	.34	1.0	0	0	.35	1.0	0	0	.30	1.0	0	0	.30	1.0	0	0	.22	1.0	0	0	26
18-19	.06	1.67	4.0	.13	68	1.99	3.5	.23	195	2.08	3.5	.28	60	2.12	3.5	.28	116	1.91	3.5	.21	166	1.68	4.0	.13	123	728
22-23	.97	1.27	4.0	.21	109	1.23	4.0	.20	170	1.16	4.0	.20	43	1.07	4.0	.19	79	1.11	4.0	.19	150	1.16	4.0	.20	189	740
26	1.19	4.04	4.5	1.63	848	3.60	4.0	1.45	1,230	4.05	4.0	1.68	361	4.03	4.0	1.68	697	3.08	4.0	1.23	970	2.03	3.5	.55	520	4,630
28-29	2.80	.17	.50	.01	5	.38	1.0	.15	127	.26	.50	.07	15	.32	.50	.13	54	.41	1.0	.17	134	.56	1.5	.32	303	638
30	2.62	.12	1.0	0	0	.17	1.0	0	0	.46	1.5	.15	32	.61	1.5	.26	108	.29	1.0	.03	24	.05	1.0	0	0	164
May 4	1.26	.27	1.0	0	0	.54	1.25	.15	127	.58	.75	.21	45	.34	.50	.06	25	.44	1.0	.06	47	.43	1.5	.03	28	272
9	.55	.81	2.5	.13	68	.73	3.0	.07	59	.74	3.0	.07	15	.71	3.0	.07	29	.74	3.0	.07	55	.60	3.0	.04	38	264
11	.81	.85	1.25	.24	125	1.28	1.25	.41	348	1.06	1.25	.33	71	1.41	1.25	.45	187	1.69	1.25	.60	473	2.02	1.25	.72	681	1,880
12	1.86	.97	3.0	.29	151	.38	4.0	.01	8	.39	4.0	.01	2	.30	4.0	0	0	.32	4.0	0	0	.22	4.0	0	0	161
13	1.83	.76	.50	.37	192	.83	.50	.43	365	.78	.50	.38	82	.72	.50	.35	145	.83	.50	.43	339	.79	.50	.39	369	1,490
17	1.07	1.42	.75	.62	322	1.31	.50	.60	509	1.29	.75	.56	120	1.35	1.0	.55	228	1.35	.75	.59	466	1.21	.50	.58	549	2,190
18	1.90	.74	3.0	.20	104	.72	3.0	.19	161	.70	3.0	.18	39	.81	3.0	.22	91	.81	3.0	.22	174	.76	3.0	.20	189	758
23	.87	1.89	1.5	.35	182	1.24	1.0	.46	390	1.37	1.0	.50	108	1.18	.50	.50	208	.89	.75	.30	237	.68	.75	.19	180	1,300

*Antecedent precipitation index

Table 7.--Runoff estimates for study area using six subareas for all storms where average rainfall on any subarea exceeded 0.40 inch--Continued.

Date of storm	API* (in)	Subarea 1 Avg. rain (in)	Subarea 1 Duration (hr)	Subarea 1 Estimated runoff (in)	Subarea 1 Estimated runoff (ac-ft)	Subarea 2 Avg. rain (in)	Subarea 2 Duration (hr)	Subarea 2 Estimated runoff (in)	Subarea 2 Estimated runoff (ac-ft)	Subarea 3 Avg. rain (in)	Subarea 3 Duration (hr)	Subarea 3 Estimated runoff (in)	Subarea 3 Estimated runoff (ac-ft)	Subarea 4 Avg. rain (in)	Subarea 4 Duration (hr)	Subarea 4 Estimated runoff (in)	Subarea 4 Estimated runoff (ac-ft)	Subarea 5 Avg. rain (in)	Subarea 5 Duration (hr)	Subarea 5 Estimated runoff (in)	Subarea 5 Estimated runoff (ac-ft)	Subarea 6 Avg. rain (in)	Subarea 6 Duration (hr)	Subarea 6 Estimated runoff (in)	Subarea 6 Estimated runoff (ac-ft)	Total (ac-ft)
1957 WATER YEAR.--Continued																										
1957																										
June 1	0.50	0.31	0.50	0	0	0.60	0.50	0.11	93	0.58	0.75	0.10	22	0.75	1.0	0.13	54	0.78	0.75	0.16	126	0.73	0.50	0.15	142	437
5	.55	.20	1.5	0	0	.40	1.5	0	0	.58	1.5	.07	15	.49	1.5	.03	12	.51	1.5	.04	32	.39	1.5	0	0	59
12	.12	1.43	.40	.32	166	1.06	.40	.21	178	.84	.40	.13	28	.86	.40	.13	54	.81	.40	.12	95	.72	.40	.09	85	606
July 23	.19	.45	.75	0	0	.25	.75	0	0	.18	1.5	0	0	.15	2.0	0	0	.34	1.25	0	0	1.08	1.0	.16	151	151
Aug. 5	.08	.36	.75	0	0	.79	.75	0	0	.54	.75	0	0	.42	.75	0	0	.52	1.0	0	0	.23	1.0	0	0	0
Sept. 3	0	.31	2.0	0	0	.38	2.0	0	0	.16	2.0	0	0	.12	2.0	0	0	.20	2.0	0	0	.51	2.0	0	0	0
11	.11	1.47	1.75	.16	83	.53	2.0	0	0	.62	2.0	0	0	.77	2.0	.01	4	.57	2.0	0	0	.50	2.0	0	0	87
1958 WATER YEAR																										
1957																										
Oct. 13	.02	.95	4.0	0	0	1.44	2.0	.05	42	1.29	2.5	.03	6	1.28	2.0	.04	17	1.58	1.5	.06	47	1.95	1.0	.12	114	226
14	1.22	1.12	5.0	.05	26	.97	5.0	.03	25	.94	5.0	.03	6	.93	5.0	.03	12	1.06	5.0	.05	39	1.16	5.0	.06	57	165
15	1.83	.54	2.0	.04	21	.44	2.0	0	0	.43	2.0	0	0	.43	2.0	0	0	.48	2.0	.02	16	.51	2.0	.03	28	65
Nov. 3	.14	.33	7.0	0	0	.34	7.0	0	0	.47	7.0	0	0	.51	7.0	0	0	.33	7.0	0	0	.16	7.0	0	0	0
5	.46	.89	3.5	.04	21	.80	4.0	.02	17	.82	4.0	.02	4	.83	3.0	.05	21	.76	4.0	.02	16	.69	5.0	.01	9	88
24	.18	.91	5.5	0	0	.94	5.0	0	0	.97	5.0	.01	2	.98	5.0	.01	4	1.00	5.0	.02	16	1.02	5.0	.02	19	41
Dec. 24-25	.01	.93	21.0	0	0	.99	18.0	0	0	1.00	22.0	0	0	1.04	21.0	0	0	1.08	18.0	0	0	.88	15.0	0	0	0
1958																										
Jan. 4-5	.10	.63	21.0	0	0	.64	21.0	0	0	.60	21.0	0	0	.71	21.0	0	0	.69	21.0	0	0	.70	21.0	0	0	0
22-23	.23	.75	15.0	0	0	.80	15.0	0	0	.65	18.0	0	0	.55	18.0	0	0	.73	18.0	0	0	.86	18.0	0	0	0
Feb. 21	.28	.54	7.0	0	0	.61	7.0	0	0	.57	7.0	0	0	.53	7.0	0	0	.57	7.0	0	0	.64	7.0	0	0	0
22	.70	1.64	14.0	.08	42	1.68	14.0	.09	76	1.64	14.0	.08	17	1.50	14.0	.07	29	1.53	14.0	.07	55	1.55	14.0	.07	66	285
Mar. 6	.46	.35	2.0	0	0	.69	2.0	.09	76	.67	2.0	.09	19	.63	2.0	.07	29	.85	2.0	.15	118	.80	2.0	.13	123	365
12	.36	.29	4.0	0	0	.50	4.0	0	0	.49	4.0	0	0	.43	4.0	0	0	.56	4.0	0	0	.58	4.0	0	0	0
22	.11	.55	.50	.05	26	.38	.50	0	0	.57	.50	.06	13	.48	.50	.02	8	.26	.50	0	0	.05	.50	0	0	47
Apr. 8	.02	.15	2.0	0	0	.16	2.0	0	0	.29	2.0	0	0	.59	2.0	0	0	.38	2.0	0	0	.24	2.0	0	0	0
13	.10	.86	10.0	0	0	1.06	10.0	0	0	.98	10.0	0	0	1.13	10.0	.01	4	1.24	10.0	.01	8	1.14	10.0	.01	9	21
20	.44	1.05	5.0	.07	36	.89	5.0	.03	25	.97	5.0	.05	11	.78	5.0	.01	4	.61	5.0	0	0	.73	5.0	.01	9	85
30	.16	.08	1.0	0	0	.32	1.0	0	0	.33	1.0	0	0	.52	1.0	.02	8	.46	1.0	0	0	.44	1.0	0	0	8
May 2	.27	.15	.50	0	0	.41	.50	0	0	.40	.75	0	0	.21	1.0	0	0	.26	.75	0	0	.18	.50	0	0	0
2	.50	1.20	.25	.39	203	.63	.25	.13	110	.53	.25	.07	15	.50	.25	.06	25	.62	.25	.12	95	.74	.25	.16	151	599
11	.22	.45	.25	.01	5	.14	.25	0	0	.11	.25	0	0	0	-	0	0	.02	.25	0	0	0	-	0	0	5
13	.22	1.50	3.5	.15	78	1.22	2.5	.15	127	1.31	3.0	.15	32	1.31	3.0	.15	62	1.19	3.0	.12	95	1.08	3.0	.10	95	489
June 21	.10	2.10	1.5	.35	182	1.94	1.5	.27	229	2.09	1.5	.35	75	2.31	1.5	.50	208	2.28	1.5	.50	394	1.77	1.5	.26	246	1,330
July 22	.07	.22	5.0	0	0	.32	5.0	0	0	.21	5.0	0	0	.37	5.0	0	0	.39	5.0	0	0	.51	5.0	0	0	0
Aug. 23-24	.04	2.30	5.5	.08	42	2.71	4.5	.23	195	2.83	5.75	.23	49	2.99	5.5	.29	120	2.57	4.5	.15	118	1.73	3.0	.02	19	543
Sept. 6	.13	.57	.75	0	0	.25	.40	0	0	.44	.40	0	0	.63	.25	0	0	.29	.25	0	0	.40	.25	0	0	0
7	.45	.42	4.5	0	0	.25	3.5	0	0	.28	3.0	0	0	.26	2.0	0	0	.16	2.5	0	0	.23	3.0	0	0	0
15-16	.12	1.02	11.5	0	0	.66	10.5	0	0	.63	10.5	0	0	.52	9.0	0	0	.36	9.0	0	0	.56	9.0	0	0	0
19	.46	.63	4.0	0	0	.56	3.5	0	0	.52	3.5	0	0	.45	3.0	0	0	.48	3.0	0	0	.55	3.0	0	0	0
25	.26	.53	.50	.01	5	.19	.50	0	0	.14	.50	0	0	.03	.50	0	0	.08	.50	0	0	.17	.25	0	0	5

*Antecedent precipitation index

Table 7.--Runoff estimates for study area using six subareas for all storms where average rainfall on any subarea exceeded 0.40 inch--Continued

Date of storm	API* (in)	Subarea 1				Subarea 2				Subarea 3				Subarea 4				Subarea 5				Subarea 6				Total (ac-ft)
		Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	Avg. rain (in)	Duration (hr)	Estimated runoff (in)	Estimated runoff (ac-ft)	
1959 WATER YEAR																										
1958																										
Oct. 3	0.08	0.46	4.0	0	0	0.36	4.0	0	0	0.39	4.0	0	0	0.38	4.0	0	0	0.37	4.0	0	0	0.33	4.0	0	0	0
12	.06	.35	.75	0	0	.38	.75	0	0	.18	.75	0	0	0	.75	0	0	.24	.75	0	0	.44	.75	0	0	0
28-29	.09	.35	18.0	0	0	.31	18.0	0	0	.45	18.0	0	0	.51	18.0	0	0	.37	18.0	0	0	.30	18.0	0	0	0
Nov. 14	.01	.66	2.0	0	0	.90	2.0	.01	8	.90	2.0	.01	2	.85	2.0	.01	4	.88	2.0	.01	8	.89	2.0	.01	9	31
1959																										
Apr. 8	0	.42	2.5	0	0	.37	2.0	0	0	.47	2.0	0	0	.51	2.0	0	0	.41	2.0	0	0	.31	2.0	0	0	0
10	.25	.80	4.0	0	0	.69	4.0	0	0	.72	4.0	0	0	.72	4.0	0	0	.67	4.0	0	0	.71	4.0	0	0	0
18	.23	1.16	.75	.26	135	.22	.75	0	0	.32	.50	0	0	.31	.50	0	0	.08	.75	0	0	.08	1.0	0	0	135
May 1-2	.14	.43	3.0	0	0	.37	2.5	0	0	.38	2.75	0	0	.35	2.5	0	0	.31	2.5	0	0	.30	2.5	0	0	0
5	.25	.47	3.0	0	0	.27	1.25	0	0	.32	2.0	0	0	.29	1.5	0	0	.21	1.25	0	0	.12	1.0	0	0	0
10	.17	.18	.40	0	0	.21	.50	0	0	.25	.50	0	0	.33	.50	0	0	.38	.50	0	0	.50	.75	.02	19	19
15	.17	1.20	7.0	.03	16	1.51	7.0	.05	42	1.35	7.0	.04	9	1.24	7.0	.03	12	1.42	7.0	.04	32	1.80	7.0	.08	76	187
22	.37	.84	4.5	.01	5	.73	3.5	.01	8	.59	4.0	0	0	.56	3.5	0	0	.61	4.0	0	0	.85	4.0	.01	9	22
June 1	.13	1.71	.50	.38	198	1.92	.75	.39	331	1.75	.50	.38	82	1.64	.50	.36	149	1.65	.75	.35	276	1.68	1.0	.32	303	1,340
2	1.46	.47	.25	.14	73	.55	.25	.19	161	.49	.25	.15	32	.47	.25	.14	58	.48	.25	.14	110	.51	.25	.16	151	585
3	1.56	1.75	1.0	.66	343	1.61	1.0	.64	543	1.43	1.5	.50	108	.72	2.0	.15	62	.91	1.5	.25	197	.79	1.5	.20	189	1,440
3-4	2.71	2.43	2.0	1.30	676	2.66	2.0	1.45	1,230	2.75	2.0	1.54	331	2.62	2.0	1.43	593	2.36	2.0	1.21	955	2.18	2.0	1.08	1,022	4,810
8	2.14	0	-	0	0	.15	-	0	0	.01	-	0	0	0	-	0	0	.08	-	0	0	.42	.50	.15	142	142
23-24	.10	.79	3.0	0	0	.52	2.75	0	0	.54	3.25	0	0	.47	3.5	0	0	.57	2.75	0	0	.59	2.0	0	0	0
25-26	.13	1.62	10.5	.02	10	2.23	11.5	.14	119	2.36	12.0	.14	30	2.52	12.0	.20	83	2.86	11.5	.38	300	3.00	11.0	.40	378	920
July 2	.82	.71	.50	.20	104	.40	.50	.02	17	.24	.50	0	0	.01	-	0	0	.01	-	0	0	.13	.50	0	0	121
15	.08	.30	.50	0	0	.46	.50	0	0	.40	.50	0	0	0	-	0	0	.16	.50	0	0	.18	.50	0	0	0
18	.16	.41	1.75	0	0	.61	1.25	0	0	.49	1.75	0	0	.04	2.0	0	0	.28	1.5	0	0	.40	1.0	0	0	0
19	.42	2.00	6.0	.20	104	2.00	5.5	.20	170	2.21	6.0	.30	64	1.86	6.0	.15	62	1.82	5.5	.16	126	1.63	5.0	.16	151	677
20	1.82	.80	2.0	.29	151	.79	2.0	.29	246	.83	1.25	.37	80	1.03	2.0	.41	170	1.00	2.5	.36	284	1.16	3.0	.39	369	1,300
21	2.24	3.25	4.5	1.45	754	3.31	5.0	1.45	1,230	3.43	4.5	1.54	331	3.21	4.5	1.43	593	3.29	5.0	1.45	1,144	3.51	6.0	1.48	1,400	5,450
Aug. 8	.10	.14	.50	0	0	.40	.50	0	0	.27	.50	0	0	.41	.50	0	0	.38	.50	0	0	.67	.50	.01	9	9
31	.10	.81	2.0	0	0	.71	1.25	0	0	.73	2.0	0	0	.69	2.0	0	0	.82	1.25	0	0	.72	.50	0	0	0
Sept. 30	.06	2.09	9.0	.06	31	1.39	6.5	0	0	1.38	9.0	0	0	1.06	9.0	0	0	.74	6.5	0	0	.91	4.0	0	0	31
1960 WATER YEAR																										
1959																										
Oct. 3-4	.67	3.98	24.0	.46	239	4.10	24.0	.52	441	3.98	24.0	.46	99	4.27	24.0	.58	241	4.38	24.0	.63	497	4.32	24.0	.61	577	2,090
13	.65	.70	4.5	0	0	.91	6.0	0	0	.84	6.0	0	0	.82	7.0	0	0	.92	7.0	0	0	1.03	7.0	0	0	0
Nov. 3	.13	.77	1.0	.01	5	.60	.50	.01	8	.67	.50	.02	4	.60	.50	.01	4	.54	.50	0	0	.46	.50	0	0	21
Dec. 14-15	.09	.62	5.0	0	0	.62	5.0	0	0	.59	5.0	0	0	.64	5.0	0	0	.73	5.0	0	0	.71	5.0	0	0	0
16	.58	.65	7.0	0	0	.62	7.0	0	0	.71	7.0	0	0	.70	7.0	0	0	.63	7.0	0	0	.54	7.0	0	0	0
16-17	1.19	.40	8.0	0	0	.39	8.0	0	0	.40	8.0	0	0	.39	8.0	0	0	.40	8.0	0	0	.41	8.0	0	0	0
31	.07	1.12	5.0	.03	16	1.08	5.0	.03	25	1.03	5.0	.02	4	1.07	5.0	.03	12	1.09	5.0	.03	24	1.06	5.0	.03	28	109
1960																										
Jan. 4-5	.47	1.35	14.0	.05	26	1.32	14.0	.05	42	1.26	14.0	.04	9	1.25	14.0	.04	17	1.33	14.0	.05	39	1.32	14.0	.05	47	180
12	.37	.40	.50	.01	5	.38	.50	.01	8	.45	.50	.03	6	.48	.50	.04	17	.46	.50	.03	24	.38	.50	.01	9	69
13	.62	.79	2.5	.14	73	.81	2.0	.19	161	.74	2.5	.13	28	.83	3.0	.12	50	.98	2.5	.18	142	.99	2.0	.23	218	672
Feb. 2-3	.02	1.18	2.5	.14	73	.79	2.5	.03	25	.81	2.5	.03	6	.74	2.5	.02	8	.87	2.5	.05	39	.84	2.5	.04	38	189
Mar 24	0	.46	1.5	0	0	.37	1.5	0	0	.39	1.5	0	0	.37	1.5	0	0	.34	1.5	0	0	.33	1.5	0	0	0

*Antecedent precipitation index

Table 7.--Runoff estimates for study area using six subareas for all storms where average rainfall on any subarea exceeded 0.40 inch--Continued

Date of storm	API*	Subarea 1				Subarea 2				Subarea 3				Subarea 4				Subarea 5				Subarea 6				Total
		Avg. rain	Duration	Estimated runoff		Avg. rain	Duration	Estimated runoff		Avg. rain	Duration	Estimated runoff		Avg. rain	Duration	Estimated runoff		Avg. rain	Duration	Estimated runoff		Avg. rain	Duration	Estimated runoff		
	(in)	(in)	(hr)	(in)	(ac-ft)	(in)	(hr)	(in)	(ac-ft)	(in)	(hr)	(in)	(ac-ft)	(in)	(hr)	(in)	(ac-ft)	(in)	(hr)	(in)	(ac-ft)	(in)	(hr)	(in)	(ac-ft)	(ac-ft)
1960 WATER YEAR.--Continued																										
1960																										
Apr. 24	0.01	0.42	0.40	0	0	0.63	0.25	0.03	25	1.16	0.50	0.21	45	1.70	0.75	0.35	145	1.06	0.50	0.19	150	0.73	0.25	0.08	76	441
25	.66	.64	.50	.15	78	.83	.50	.21	178	.99	.50	.34	73	.91	.50	.29	120	.75	.50	.20	158	.56	.50	.10	95	702
26	1.08	.39	1.5	0	0	.34	2.0	0	0	.40	2.0	0	0	.47	2.0	.06	25	.49	2.0	.07	55	.38	2.0	0	0	80
27	1.18	.46	.25	.10	52	.37	.40	.07	59	.47	.40	.10	22	.36	.50	.06	25	.30	.50	.01	8	.07	.50	0	0	166
29	.93	.37	1.0	.01	5	.50	.75	.10	85	.37	1.0	.01	2	.29	1.0	0	0	.62	.75	.15	118	.85	.50	.29	274	484
May 18	.10	.80	.50	.13	68	.44	.50	0	0	.59	.50	.06	13	.49	.50	.01	4	.25	.50	0	0	.05	.50	0	0	85
27	.12	1.17	.50	.27	140	.47	.50	.01	8	.54	.50	.03	6	.51	.50	.03	12	.32	.50	0	0	.17	.50	0	0	166
30	.31	.45	2.0	0	0	.38	2.0	0	0	.27	1.75	0	0	.22	1.5	0	0	.25	1.75	0	0	.35	2.0	0	0	0
June 7	.11	.42	.25	0	0	.10	.25	0	0	.14	.25	0	0	.04	.25	0	0	.04	.25	0	0	.02	.25	0	0	0
July 16	.01	.28	.50	0	0	.69	.50	.02	17	.16	.50	0	0	0	-	0	0	.32	.50	0	0	1.06	.50	.15	142	159
19	.38	.44	1.0	0	0	.18	1.75	0	0	.19	2.0	0	0	.42	2.5	0	0	.46	2.25	0	0	.29	2.0	0	0	0
24	.34	.50	1.0	.01	5	.18	1.5	0	0	.22	1.5	0	0	0	-	0	0	.03	-	0	0	0	-	0	0	5
26	.31	.26	.50	0	0	.23	.75	0	0	.40	1.0	0	0	.34	1.5	0	0	.24	1.5	0	0	.04	1.5	0	0	0
Aug. 9	.02	1.00	1.0	0	0	1.37	1.75	.03	25	.97	1.25	0	0	.34	1.0	0	0	1.03	1.5	0	0	1.71	2.0	.03	28	53
10	.99	.54	4.5	0	0	.50	2.5	0	0	.54	5.5	0	0	.76	7.0	0	0	.78	4.0	0	0	.91	1.0	.01	9	9
Sept. 23	0	1.31	2.0	.11	57	1.09	3.0	.05	42	1.35	2.5	.08	17	1.44	2.5	.09	37	1.08	3.0	.04	32	.72	4.0	0	0	185
24	.86	.23	1.0	0	0	.44	1.0	0	0	.41	1.0	0	0	.59	1.0	.07	29	.58	1.0	.07	55	.74	1.0	.14	132	216

*Antecedent precipitation index

Table 8.--Comparison of estimated and observed runoff, in inches, for study area. Estimated runoff based on six subareas

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water year
1954 Water Year													
Estimated	0.49	0	0	0	0	0.13	0.36	0.12	0.04	0.02	0	0	1.16
Observed	.50	0	0	0	0	.17	.28	.17	*	*	0	0	1.12
Difference	-.01	0	0	0	0	-.04	+.08	-.05	+.04	+.02	0	0	+.04
1955 Water Year													
Estimated	*	*	0	0	.03	.01	.02	2.05	.86	.86	.04	.48	4.35
Observed	*	.05	0	0	.03	.03	0	2.04	.96	.92	.06	.50	4.59
Difference	*	-.05	0	0	0	-.02	+.02	+.01	-.10	-.06	-.02	-.02	-.24
1956 Water Year													
Estimated	0	0	0	0	0	0	2.17	.02	0	0	.01	.01	2.21
Observed	0	0	0	0	0	0	2.27	*	0	0	*	.01	2.28
Difference	0	0	0	0	0	0	-.10	+.02	0	0	+.01	0	-.07
1957 Water Year													
Estimated	.09	.03	0	0	0	.24	1.86	2.23	.29	.04	0	.02	4.80
Observed	.07	.05	0	0	0	.09	2.09	2.63	.20	.01	0	.01	5.15
Difference	+.02	-.02	0	0	0	+.15	-.23	-.40	+.09	+.03	0	+.01	-.35
1958 Water Year													
Estimated	.12	.03	0	0	.08	.11	.03	.29	.36	0	.15	*	1.17
Observed	.12	.04	0	*	.17	.12	.04	.11	.07	0	.10	0	.77
Difference	0	-.01	0	*	-.09	-.01	-.01	+.18	+.29	0	+.05	*	+.40
1959 Water Year													
Estimated	0	.01	0	0	0	0	.04	.06	2.48	2.02	*	.01	4.62
Observed	0	0	0	0	0	0	*	.01	2.25	2.01	*	.01	4.28
Difference	0	+.01	0	0	0	0	+.04	+.05	+.23	+.01	*	0	+.34
1960 Water Year													
Estimated	.56	.01	.03	.25	.05	0	.47	.07	0	.04	.02	.11	1.61
Observed	.54	*	.03	.36	.07	*	.19	.01	0	0	.01	0	1.21
Difference	+.02	+.01	0	-.11	-.02	*	+.28	+.06	0	+.04	+.01	+.11	+.40
7-Year Totals													
Estimated	1.26	.08	.03	.25	.16	.49	4.95	4.84	4.03	2.98	.22	.63	19.92
Observed	1.23	.14	.03	.36	.27	.41	4.87	4.97	3.48	2.94	.17	.53	19.40
Difference	+.03	-.06	0	-.11	-.11	+.08	+.08	+.13	+.55	+.04	+.05	+.10	+.52

* Less than 0.01 inch.
Note.--Difference based on observed runoff.

Table 9.--Runoff estimates for study area based on weighted-mean rainfall

Date of storm	API* (inches)	Storm WMR (inches)	Duration of storm (hours)	Estimated runoff (inches)
1954 Water Year:				
Oct. 3-4	0.21	3.94	12.5	0.49
Oct. 29	.05	.35	2.0	0
Mar. 24	0	.90	1.0	.11
Apr. 12	.01	1.17	1.0	.21
Apr. 22-23	.14	.81	7.0	0
Apr. 27	.39	.63	.50	.12
Apr. 30	.52	.57	2.0	.06
May 6	.34	.17	.25	0
May 11	.38	1.12	4.0	.12
June 7	.02	.60	2.0	0
June 22	.02	.45	.75	0
July 31	0	1.11	4.5	.01
Aug. 31	.01	.48	1.5	0
1955 Water Year:				
Oct. 5	.05	.90	2.0	0
Oct. 27	.01	.82	3.5	0
Nov. 14	.07	.91	6.5	0
Jan. 9	.03	.48	3.0	0
Feb. 4	.07	.78	2.5	.02
Mar. 13	0	.32	.75	0
Mar. 18	.10	.26	.25	0
Apr. 11	.12	.32	.75	0
May 10-11	.14	2.55	1.5	.75
May 11	2.69	.58	.25	.36
May 16-17	1.07	.54	.25	.17
May 17	1.61	1.94	7.0	.36
May 18-19	2.84	.69	1.5	.34
June 4	.11	.98	1.0	.14
June 6	.76	.76	.25	.20
June 8	.97	.67	2.0	.12
June 14-15	.48	1.16	.25	.54
July 15	.04	.31	1.5	0
July 16-17	.28	2.16	5.0	.31
July 17-18	2.44	1.44	2.75	.59
Aug. 9	.03	.14	.25	0
Aug. 18	.06	.35	.25	0
Aug. 30	.13	.71	1.0	0
Sept. 10-11	.07	.28	.50	0
Sept. 22	.03	2.82	6.0	.40
Sept. 24	1.82	.42	.50	.10
1956 Water Year:				
Nov. 30	0	.51	11.0	0
Jan. 17	0	.88	8.5	0
Jan. 21	.36	.56	4.5	0
Apr. 5	0	.23	2.0	0
Apr. 21	.14	.48	6.0	0
Apr. 29	.10	.25	1.0	0
Apr. 30	.28	.67	.75	.07
Apr. 30-May 1	.95	4.85	5.0	2.05
May 14	.32	.38	.50	0
May 23-24	.09	.82	12.0	0
June 9	.03	.16	3	0
Aug. 19	0	.69	.50	0
Aug. 28	.09	.67	4.5	0
Sept. 6	.10	.45	1.5	0
1957 Water Year:				
Oct. 15	.01	.69	2.5	0
Oct. 18	.36	.96	.50	.08
Oct. 30	.09	.77	2.0	0
Nov. 2	.44	.31	1.25	0
Nov. 4	.48	.55	3.0	0
Dec. 18-19	.01	1.06	36.0	0
Feb. 16	.04	.46	8.0	0
Mar. 10	.01	.51	1.5	0
Mar. 20	.18	1.02	.50	.25
Apr. 3	.16	.33	1.0	0
Apr. 18-19	.06	1.84	4.0	.18
Apr. 22-23	.97	1.18	4.0	.21
Apr. 26	1.19	3.19	4.0	1.25
Apr. 28-29	2.80	.39	1.0	.15
Apr. 30	2.62	.20	1.25	0
May 4	1.26	.41	1.0	.06
May 9	.55	.71	3.0	.07
May 11	.81	1.51	1.25	.48
May 12	1.86	.43	4.0	0
May 13	1.83	.79	.50	.42
May 17	1.07	1.31	.75	.57
May 18	1.90	.76	3.0	.20
May 23	.87	1.11	1.25	.37
June 1	.50	.63	.50	.10
June 5	.55	.43	1.5	0
June 12	.21	.96	.40	.02
July 23	.19	.60	1.0	.03
Aug. 5	.08	.46	.75	0
Sept. 3	0	.36	2.0	0
Sept. 11	.11	.73	2.0	.01
1958 Water Year:				
Oct. 13	0.02	1.51	2.0	0.05
Oct. 14	1.22	1.07	5.0	.06
Oct. 15	1.83	.49	2.0	.01
Nov. 3	.14	.30	7.0	0
Nov. 5	.46	.76	4.0	.01
Nov. 24	.18	.97	5.0	0
Dec. 24-25	.01	.95	20.0	0
Jan. 4-5	.10	.67	21.0	0
Jan. 22-23	.23	.76	17.0	0
Feb. 21	.28	.59	7.0	0
Feb. 22	.70	1.58	14.0	.09
Mar. 6	.46	.67	2.0	.08
Mar. 12	.36	.48	4.0	0
Mar. 22	.11	.30	.50	0
Apr. 8	.02	.28	2.0	0
Apr. 13	.10	1.07	10.0	0
Apr. 20	.44	.81	5.0	.02
Apr. 30	.16	.36	1.0	0
May 2	.27	.23	.75	0
May 2	.50	.75	.25	.20
May 11	.22	.12	.25	0
May 13	.22	1.22	3.0	.15
June 21	.10	2.00	1.5	.35
July 22	.07	.38	5.0	0
Aug. 23-24	.04	2.33	5.0	.12
Sept. 6	.13	.43	.50	0
Sept. 7	.45	.26	3.5	0
Sept. 15-16	.12	.66	10.0	0
Sept. 19	.46	.53	3.5	0
Sept. 25	.26	.22	.50	0
1959 Water Year:				
Oct. 3	.08	.37	12.5	0
Oct. 12	.06	.31	.75	0
Oct. 28-29	.09	.35	18.0	0
Nov. 14	.01	.84	2.0	.01
Apr. 8	0	.39	2.0	0
Apr. 10	.25	.72	4.0	0
Apr. 18	.23	.34	.75	0
May 1-2	.14	.35	2.75	0
May 5	.25	.26	2.0	0
May 10	.17	.34	.50	0
May 15	.17	1.52	7.0	.09
May 22	.37	.74	4.0	.01
June 1	.13	1.70	.75	.34
June 2	1.46	.49	.25	.15
June 3	1.56	1.15	1.5	.48
June 3-4	2.71	2.42	2.0	1.30
June 8	2.14	.18	.50	0
June 23-24	.10	.61	3.0	0
June 25-26	.13	2.54	11.0	.24
July 2	.82	.26	.50	0
July 15	.08	.23	.50	0
July 18	.16	.37	1.5	0
July 19	.42	1.85	5.5	.19
July 20	1.82	.98	2.25	.35
July 21	2.24	3.36	5.0	1.48
Aug. 8	.10	.46	.50	0
Aug. 31	.10	.73	1.0	0
Sept. 30	.06	1.24	7.0	0
1960 Water Year:				
Oct. 3-4	.67	4.18	24.0	.55
Oct. 13	.65	.89	6.0	0
Nov. 3	.13	.57	.50	0
Dec. 14-15	.09	.64	5.0	0
Dec. 16	.58	.61	7.0	0
Dec. 16-17	1.19	.39	8.0	0
Dec. 31	.07	1.08	5.0	.03
Jan. 4-5	.47	1.31	14.0	.04
Jan. 12	.37	.41	.50	.02
Jan. 13	.62	.86	2.5	.15
Feb. 2-3	.02	.89	2.5	.04
Mar. 24	0	.37	1.5	0
Apr. 24	.01	.82	.50	.14
Apr. 25	.66	.69	.50	.16
Apr. 26	1.08	.39	2.0	.01
Apr. 27	1.18	.27	.40	0
Apr. 29	.93	.56	.75	.12
May 18	.10	.35	.50	0
May 27	.12	.49	.50	.01
May 30	.31	.32	1.75	0
June 7	.11	.11	.25	0
July 16	.01	.57	.50	.01
July 19	.38	.32	2.0	0
July 24	.34	.15	1.5	0
July 26	.31	.20	1.0	0
Aug. 9	.02	1.21	1.5	.04
Aug. 10	.99	.71	4.5	0
Sept. 23	0	1.08	3.0	.04
Sept. 24	.86	.54	1.0	.06

*Antecedent precipitation index

Table 10.--Comparison of estimated and observed runoff, in inches, for study area. Runoff estimates based on weighted-mean rainfall

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Water year
1954 Water Year													
Estimated	0.49	0	0	0	0	0.11	0.39	0.12	0	0.01	0	0	1.12
Observed	.50	0	0	0	0	.17	.28	.17	*	*	0	0	1.12
Difference	-.01	0	0	0	0	-.06	+.11	-.05	*	+.01	0	0	0
1955 Water Year													
Estimated	0	0	0	0	.02	0	0	1.98	1.00	.90	0	.50	4.40
Observed	*	.05	0	0	.03	.03	0	2.04	.96	.92	.06	.50	4.59
Difference	*	-.05	0	0	-.01	-.03	0	-.06	+.04	-.02	-.06	0	-.19
1956 Water Year													
Estimated	0	0	0	0	0	0	2.12	0	0	0	0	0	2.12
Observed	0	0	0	0	0	0	2.27	*	0	0	*	.01	2.28
Difference	0	0	0	0	0	0	-.15	*	0	0	*	-.01	-.16
1957 Water Year													
Estimated	.08	0	0	0	0	.25	1.79	2.17	.12	.03	0	.01	4.45
Observed	.07	.05	0	0	0	.09	2.09	2.63	.20	.01	0	.01	5.15
Difference	+.01	-.05	0	0	0	+.16	-.30	-.46	-.08	+.02	0	0	-.70
1958 Water Year													
Estimated	.12	.01	0	0	.09	.08	.02	.35	.35	0	.12	0	1.14
Observed	.12	.04	0	*	.17	.12	.04	.11	.07	0	.10	0	.77
Difference	0	-.03	0	*	-.08	-.04	-.02	+.24	+.28	0	+.02	0	+.37
1959 Water Year													
Estimated	0	.01	0	0	0	0	0	.10	2.51	2.02	0	0	4.64
Observed	0	0	0	0	0	0	*	.01	2.25	2.01	*	.01	4.28
Difference	0	+.01	0	0	0	0	*	+.09	+.26	+.01	*	-.01	+.36
1960 Water Year													
Estimated	.55	0	.03	.21	.04	0	.43	.01	0	.01	.04	.10	1.42
Observed	.54	*	.03	.36	.07	*	.19	.01	0	0	.01	0	1.21
Difference	+.01	*	0	-.15	-.03	*	+.24	0	0	+.01	+.03	+.10	+.21
7-Year Totals													
Estimated	1.24	.02	.03	.21	.15	.44	4.75	4.73	3.98	2.97	.16	.61	19.29
Observed	1.23	.14	.03	.36	.27	.41	4.87	4.97	3.48	2.94	.17	.53	19.40
Difference	+.01	-.12	0	-.15	-.12	+.03	-.12	-.24	+.50	+.03	-.01	+.08	-.11

* Less than 0.01 inch.
Note.--Difference based on observed runoff.

is a comparison of the estimated runoff and observed runoff for the 7-year period. Differences were computed using observed runoff as the base.

Comparison of Rainfall-Runoff Estimates

In order that the estimated runoff by the above two procedures and the observed runoff may be compared, the results are presented graphically on Figure 17. The figure shows that the estimated runoff by either procedure generally shows a fair degree of correlation on a monthly basis. Tables 8 and 10 show good agreement on an annual basis and excellent agreement for the 7-year total runoff. Total runoff for the 7-year period was estimated within 1 percent and 3 percent, respectively, by the WMR and six subarea methods. No significant improvement in results was noted when areal distribution was considered, indicating that this factor is not as significant for this study area as it was thought to be. Some improvement was noted for small, very unevenly distributed storms when perhaps only a small portion of the study area contributed runoff. For storms of this nature, WMR would indicate no runoff. However, storms of this nature generally contribute small amounts of runoff, usually less than 0.02 inch.

WATER BUDGET OF THE STUDY AREA

Proper watershed planning necessitates the determination of factors which comprise the water budget of the watershed over a representative climatic cycle that includes an extended drought, extreme flood flows, and periods of ordinary runoff. A water budget is an accounting for the water which enters and leaves a watershed. The study area water budget used is of the form

$$C = R - Q, \tag{6}$$

where C is study-area consumption
R is weighted-mean rainfall over the study area, and
Q is flow of water out of the watershed.

In this study area, there is no base flow; therefore, Q is runoff at the stream-gaging station. Equation 6 may be rewritten as

$$C = R - Q_s, \tag{7}$$

where Q_s is surface runoff as recorded at the stream-gaging station.

With a rain-gage density of one gage per 3.7 square miles and continuous record of streamflow out of the study area, the factors R and Q_s can be determined with a high degree of accuracy. Consumption encompasses many factors including evaporation, transpiration, infiltration, and ground-water flow out of the study area. For this study, consumption (C) is defined as the difference between rainfall and runoff and no attempt was made to separate the various factors.

Table 11 shows the study area water budget for the period October 1951 to September 1960. Table 11 shows that average consumption for the 9 water years, 1952-60, was 177.33 inches or 89.3 percent of the 198.47 inches of rainfall. However, this 9-year average consumption may not be representative of the long-term average consumption as the period 1952-56 was a period of relative drought.

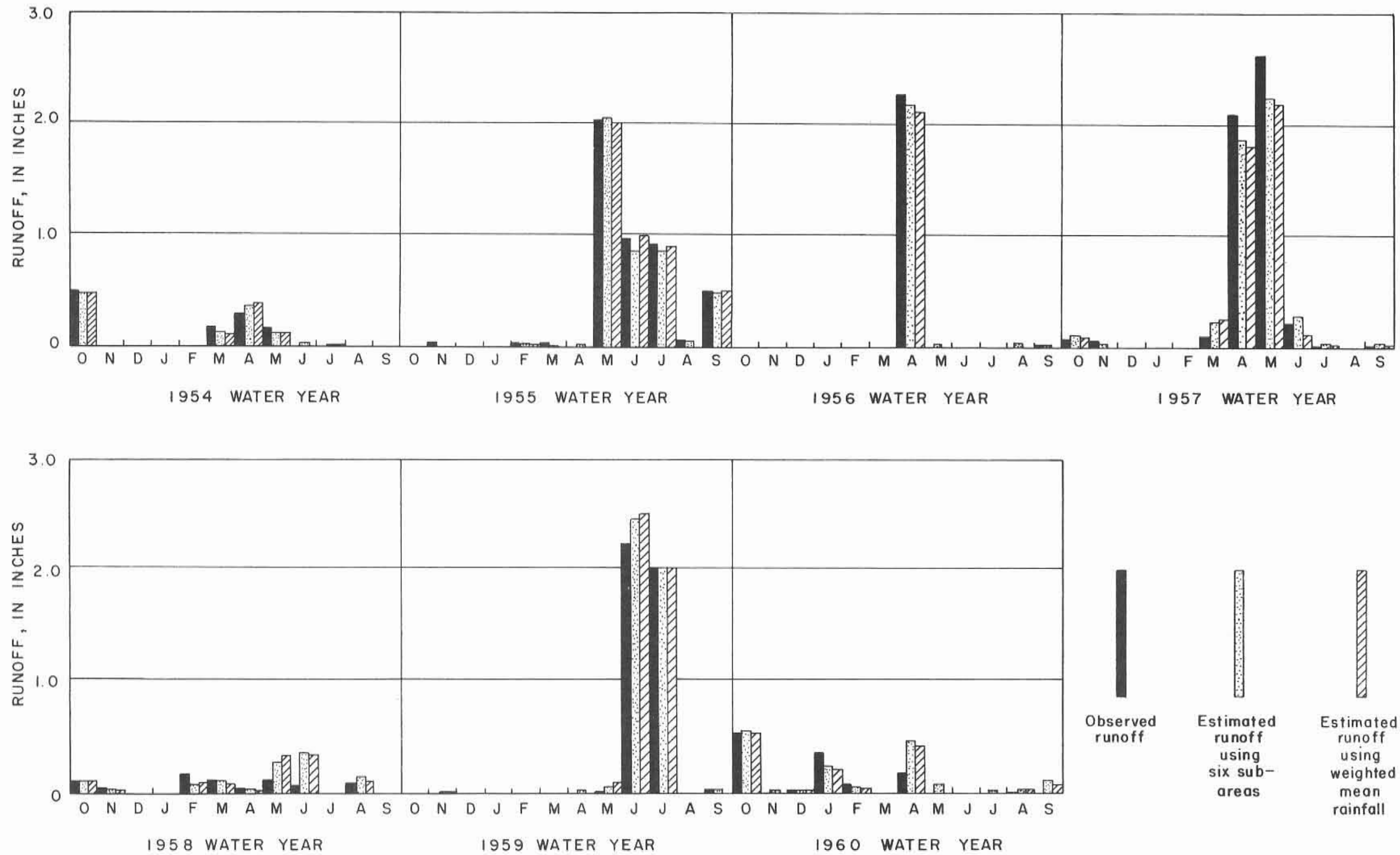

Figure 17

Comparison of Observed Runoff and Estimated Runoff for Mukewater Creek Study Area

U. S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

Table 11.--Water budget for Mukewater Creek study area

Month	WMR (inches)	Runoff (inches)	Study area consumption (inches)	
			(inches)	(percent)
1952 Water Year				
Oct.	1.34	0	1.34	100
Nov.	.43	0	.43	100
Dec.	.07	0	.07	100
Jan.	.21	0	.21	100
Feb.	.30	0	.30	100
Mar.	1.34	0	1.34	100
Apr.	2.66	.18	2.48	93.2
May	4.80	.58	4.22	87.9
June	.70	.003	.697	99.6
July	.35	0	.35	100
Aug.	.19	0	.19	100
Sept.	4.51	.14	4.37	96.9
Totals	16.90	.90	16.00	94.7
1953 Water Year				
Oct.	0	0	0	-
Nov.	2.60	.10	2.50	96.2
Dec.	1.59	.04	1.55	97.5
Jan.	.14	.001	.139	99.3
Feb.	.26	0	.26	100
Mar.	3.46	.20	3.26	94.2
Apr.	1.75	.06	1.69	96.6
May	3.18	.35	2.83	89.0
June	1.00	.01	.99	99.0
July	1.20	.01	1.19	99.2
Aug.	2.08	.05	2.03	97.6
Sept.	.57	0	.57	100
Totals	17.83	.82	17.01	95.4
1954 Water Year				
Oct.	4.61	.50	4.11	89.2
Nov.	.32	0	.32	100
Dec.	.11	0	.11	100
Jan.	.31	0	.31	100
Feb.	.21	0	.21	100
Mar.	.99	.17	.82	82.8
Apr.	3.26	.26	3.00	92.0
May	2.16	.19	1.97	91.2
June	1.11	.003	1.107	99.7
July	1.18	.001	1.179	99.9
Aug.	.65	.002	.648	99.7
Sept.	.22	0	.22	100
Totals	15.13	1.13	14.00	92.5
1955 Water Year				
Oct.	1.72	.005	1.715	99.7
Nov.	1.16	.05	1.11	95.7
Dec.	.29	0	.29	100
Jan.	.80	0	.80	100
Feb.	.88	.03	.85	96.6
Mar.	.69	.03	.66	95.7
Apr.	.70	0	.70	100
May	6.67	2.04	4.63	69.4
June	3.97	.95	3.02	76.1
July	4.15	.92	3.23	77.8
Aug.	1.63	.06	1.57	96.3
Sept.	3.52	.50	3.02	85.8
Totals	26.18	4.60	21.58	82.4
1956 Water Year				
Oct.	.04	0	.04	100
Nov.	.51	0	.51	100
Dec.	0	0	0	-
Jan.	1.44	0	1.44	100
Feb.	.64	0	.64	100
Mar.	.06	0	.06	100
1956 Water Year.--Continued				
Apr. } May }*	7.96	2.27	5.69	71.5
June	.17	0	.17	100
July	.09	0	.09	100
Aug.	1.36	.003	1.357	99.8
Sept.	.59	.01	.58	98.3
Totals	12.84	2.28	10.56	82.2
1957 Water Year				
Oct.	2.42	.07	2.35	97.1
Nov.	.86	.05	.81	94.2
Dec.	1.26	0	1.26	100
Jan.	.68	0	.68	100
Feb.	1.04	0	1.04	100
Mar.	1.87	.09	1.78	95.2
Apr.	7.46	2.04	5.42	72.7
May	7.58	2.68	4.90	64.6
June	2.22	.20	2.02	91.0
July	1.12	.01	1.11	99.1
Aug.	.52	0	.52	100
Sept.	1.57	.01	1.56	99.4
Totals	28.60	5.15	23.45	82.0
1958 Water Year				
Oct.	3.50	.12	3.38	96.6
Nov.	3.22	.04	3.18	98.8
Dec.	1.27	.001	1.269	99.9
Jan.	2.04	.005	2.035	99.8
Feb.	2.57	.17	2.40	93.4
Mar.	2.49	.12	2.37	95.2
Apr.	2.91	.04	2.87	98.6
May	2.72	.11	2.61	96.0
June	2.32	.06	2.26	97.4
July	.60	0	.60	100
Aug.	2.53	.10	2.43	96.0
Sept.	2.23	0	2.23	100
Totals	28.40	.77	27.63	97.3
1959 Water Year				
Oct.	1.40	0	1.40	100
Nov.	1.13	0	1.13	100
Dec.	.40	0	.40	100
Jan.	trace	0	trace	100
Feb.	.86	0	.86	100
Mar.	.25	0	.25	100
Apr.	1.71	.005	1.705	99.7
May	3.31	.01	3.30	99.7
June	9.20	2.25	6.95	75.5
July	7.14	2.01	5.13	71.8
Aug.	1.42	.002	1.418	99.9
Sept.	1.56	0	1.56	100
Totals	28.38	4.28	24.10	84.9
1960 Water Year				
Oct.	5.07	.54	4.53	89.3
Nov.	1.03	.005	1.025	99.5
Dec.	2.89	.01	2.88	99.7
Jan.	2.62	.37	2.25	85.9
Feb.	1.19	.07	1.12	94.1
Mar.	.37	.01	.36	97.3
Apr.	2.78	.19	2.59	93.2
May	1.60	.01	1.59	99.4
June	.58	0	.58	100
July	1.64	0	1.64	100
Aug.	2.69	.01	2.68	99.6
Sept.	1.75	0	1.75	100
Totals	24.21	1.21	23.00	95.0
9-year Totals	198.47	21.14	177.33	89.3

*Combined due to 4.85-inch rain on night of Apr. 30-May 1 from which most of runoff occurred during month of May.

Figure 18 is a graphical presentation of the water budget with the difference between monthly rainfall and runoff being the monthly consumption.

For the 9 water years, 1952-60, annual consumption expressed as a percentage of annual rainfall ranged from a minimum of 82.0 percent in 1957, to a maximum of 97.3 percent in 1958. It is interesting to note that for these 2 years the total annual rainfall was almost identical, differing by less than 1 percent. Also of interest is the fact that during 1956, the driest year of this record, the consumption was 82.2 percent, very near the minimum, whereas the maximum percentage consumption occurred during one of the wettest of the 9 years. Phenomena such as these are quite common in the western part of Texas and clearly illustrate the fact that the percentage of runoff in this area is heavily dependent upon the distribution of rainfall throughout each year rather than upon annual totals.

SUMMARY AND CONCLUSIONS

The rain-gage density analyses indicate that approximately the same rainfall totals for the 70-square-mile area could be obtained with considerably fewer gages; however, it is necessary to maintain the present rain-gage network for detailed studies of the watershed.

The flood-frequency analysis for this study compares reasonably well with the regional flood-frequency analysis. The difference in the curves may be attributed to two factors; namely, that the period of record for the Mukewater Creek study area is too short for an adequate analysis, and the regional frequency curve is largely based on an extrapolation of data from larger watersheds.

No definite conclusions can be drawn from the analyses of the unit hydrographs for this area, probably because of insufficient data and low runoff during the period of record. High runoff storms, which are desirable for unit hydrograph studies, are infrequent in this area.

The rainfall-runoff relation derived in this report indicates that monthly and annual runoff may be related to rainfall and other factors with a high degree of confidence for watersheds of this size. The estimated runoff analyzed for the 7 water years, 1954-60, compared very closely with the actual runoff. The runoff estimated by the two methods was within 1 percent and 3 percent of the 7-year total, indicating that runoff over a longer time period may be estimated with considerable confidence. The inclusion of areal distribution of rainfall as a factor influencing the runoff does not increase the accuracy of runoff estimates except for a few storms with insignificant runoff.

The water-budget study showed that during the 9 water years, 1952-60, consumption was 89.3 percent of rainfall. The study also showed conclusively that percentage of runoff is heavily dependent upon time distribution of rainfall rather than annual totals.

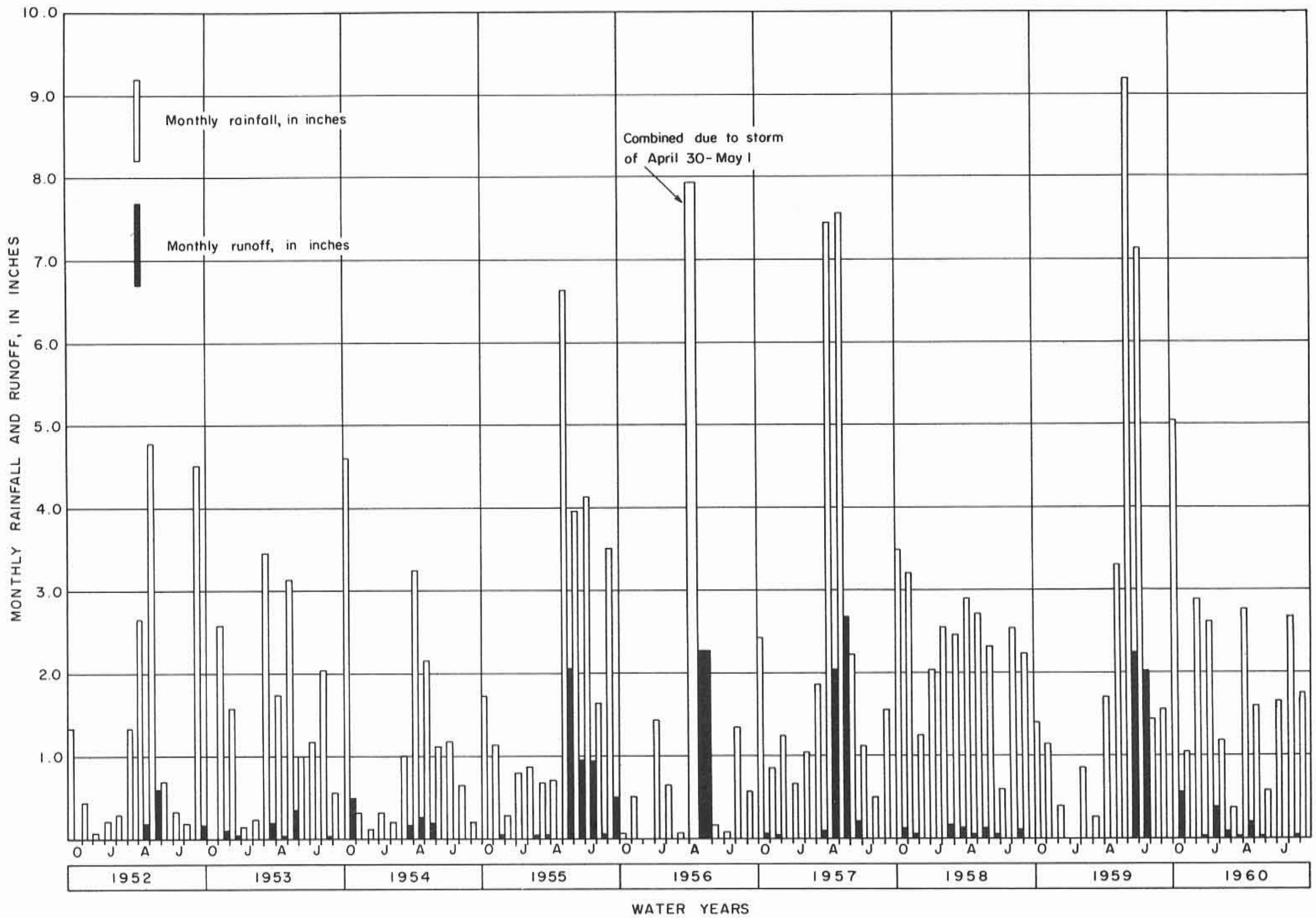

Figure 18

Plot of Monthly Rainfall and Runoff in Inches for Mukewater Creek Study Area

U. S. Geological Survey in cooperation with the Texas Water Development Board and the U.S. Soil Conservation Service

RECOMMENDATIONS AND COMMENTS

Recommendations regarding this and other small watershed investigations are as follows:

1. The data-collection program for the period was adequate and the project was well managed. However, in using the rainfall records for rainfall-runoff analyses, the time distribution, both intensity and storm period, are quite important. Records from recording gages are the basis for separating storm totals for nonrecording gages. The rain-gage density analyses in this report pointed out that approximately the same total rainfall could be obtained from fewer gages. In this watershed, it is necessary to maintain the present network because the study area will be subdivided into smaller subareas in future studies after the construction of floodwater-retarding structures.

In view of the importance of time distribution and the results of the rain-gage density analyses, it is recommended that in future studies of small watersheds where no additional development by building floodwater-retarding structures is planned the number or density of recording rain gages be increased and the total rain-gage density be decreased.

2. There should be adequate provision for instrumentation of proposed floodwater-retarding structures in order to determine evapotranspiration and seepage losses. Studies of this type require both adequate instrumentation and accurate area-capacity curves and outflow ratings for the structures.

3. Data collection should be continued for a sufficient period of time after watershed development to insure that the effects of watershed development may be evaluated throughout an extended climatic cycle that includes an extended drought, a major flood and runoff year, and a group of years where ordinary runoff occurs.

4. After sufficient data have been collected in a post-development stage of the study area, a report should be prepared evaluating the effects of watershed development. The rainfall-runoff relation in this report should be used as an aid in this study.

5. The possibility of determining a rainfall-runoff relation such as the one in this report should be investigated for other watersheds on which rainfall and runoff records are available. If the rainfall-runoff relation could be determined as a regional characteristic, it would be a valuable tool in estimating runoff from ungaged areas where only rainfall data are available.

6. Further investigations should be initiated to determine a characteristic unit hydrograph for the study area. This would require a more rigorous analysis than that included in this report.

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Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-R	12-S	13-S	14-S	15-S	16-S	17-S	18-S	19-S
	Rain gages installed in September 1953																			
1953																				
Oct. 3	0.20	0.21	0.21	0.16	0.20	0.25	0.32	0.15	0.26	0.18	0.26	0.15	0.17	0.17	0.18	0.16	0.17	0.19	0.17	0.19
3-4	3.94	3.74	3.42	3.46	3.54	4.05	5.12	3.53	4.29	3.82	4.23	3.50	4.08	4.09	4.11	3.77	3.98	4.35	3.89	4.39
23	.12	.10	.09	.11	.24	.06	.09	.10	.10	.07	.10	.08	.10	.14	.18	.12	.11	.22	.10	.12
29	.35	.20	.20	.28	.26	.24	.38	.30	.41	.25	.40	.35	.34	.44	.41	.38	.44	.44	.44	.50
Monthly Totals	4.61	4.25	3.92	4.01	4.24	4.60	5.91	4.08	5.06	4.32	4.99	4.08	4.69	4.84	4.88	4.43	4.70	5.20	4.60	5.20
Nov. 4	.14	.12	.26	.15	.14	.23	.17	.18	.12	.08	.14	.11	.10	.12	.12	.13	.12	.13	.12	.14
19	.18	.26	.21	.37	.32	.18	.18	.24	.17	.25	.14	.15	.19	.17	.12	.12	.10	.11	.12	.11
Monthly Totals	0.32	0.38	0.47	0.52	0.46	0.41	0.35	0.42	0.29	0.33	0.28	0.26	0.29	0.29	0.24	0.25	0.22	0.24	0.24	0.25
Dec. 2	.09	.20	0	0	0	.17	0	0	.06	.16	.08	.20	0	.09	0	0	.12	.15	.17	.16
22	.01	.06	0	0	0	.05	0	0	0	.03	0	.04	0	0	0	0	0	0	0	0
27	.01	.03	0	0	0	.02	0	0	0	.02	0	.04	0	0	0	0	0	0	0	0
Monthly Totals	0.11	0.29	0	0	0	0.24	0	0	0.06	0.21	0.08	0.28	0	0.09	0	0	0.12	0.15	0.17	0.16
1954																				
Jan. 13	.01	trace	trace	trace	trace	trace	.02	trace	.02	trace	.03	trace	trace	.02	.02	trace	.02	.01	trace	.01
13-14	.08	.15	.09	.08	.10	.10	.07	.09	.07	.10	.08	.11	0	.07	.05	.06	.07	.05	.06	.06
14-15	.15	.22	.17	.17	.14	.20	.15	.17	.14	.20	.17	.21	0	.15	.11	.12	.14	.11	.11	.12
21	.07	.25	.02	.12	.11	.18	.01	.06	.02	.25	trace	.15	trace	trace	0	0	trace	trace	0	0
Monthly Totals	0.31	0.62	0.28	0.37	0.35	0.48	0.25	0.32	0.25	0.55	0.28	0.47	trace	0.24	0.18	0.18	0.23	0.17	0.17	0.19
Feb. 2	.11	.15	.02	.08	.08	.10	.05	.09	.13	.13	.11	.18	.09	.13	.14	.05	.15	.09	.12	.09
19	.10	.18	.12	.22	0	.40	0	.12	.12	.50	0	.13	0	0	0	0	0	0	0	.11
Monthly Totals	0.21	0.33	0.14	0.30	0.08	0.50	0.05	0.21	0.25	0.63	0.11	0.31	0.09	0.13	0.14	0.05	0.15	0.09	0.12	0.20
Mar. 4	.04	.12	0	.03	.01	.10	.04	.01	.02	.13	.03	.13	.01	.02	.01	.01	.03	.01	0	.01
5	.05	.13	0	.02	.01	.15	.05	.01	.03	.12	.04	.21	.01	.04	.02	.01	.04	.01	0	.02
24	.90	.25	.21	.64	.50	.99	.82	.74	.82	.95	.97	1.13	.73	1.12	.80	.74	1.53	1.39	1.45	1.67
Monthly Totals	0.99	0.50	0.21	0.69	0.52	1.24	0.91	0.76	0.87	1.20	1.04	1.47	0.75	1.18	0.83	0.76	1.60	1.41	1.45	1.70
Apr. 12	1.17	1.25	1.00	1.35	1.27	2.00	1.12	.95	1.65	1.14	.99	1.40	.88	1.02	1.21	.76	.87	1.35	.64	.90
15	.08	.12	trace	.17	trace	.15	.18	trace	trace	.18	.14	.03	.05	.18	.07	.07	.06	.06	.05	.06
22-23	.81	1.68	.66	1.17	1.60	.90	.50	.47	.53	.90	.61	.60	.54	.61	.57	.55	.54	.62	1.22	.81
27	.63	.55	.50	.72	.75	.70	.47	.64	.69	.80	.47	.62	.55	.40	.51	.56	.53	.79	1.08	.77
30	.57	.57	.31	.70	.60	.66	.53	.69	.73	1.05	.58	1.05	.66	.68	.38	.30	.32	.45	.22	.30
Monthly Totals	3.26	4.17	2.47	4.11	4.22	4.41	2.80	2.75	3.60	4.07	2.79	3.70	2.68	2.89	2.74	2.24	2.32	3.27	3.21	2.84

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	*11-R	12-S	13-S	14-S	15-S	16-S	17-S	18-S	*19-S
1954																				
May 1	0.16	0.05	0.11	0.13	0.05	0.24	0.19	0.23	0.27	0.20	0.22	0.35	0.22	0.22	0.12	0.10	0.11	0.15	0.08	0.10
6	.17	.56	.05	.34	.64	.05	.05	.09	.05	.35	.06	.08	.09	.11	.10	.09	.11	.07	.08	.09
10	.26	0	.29	.34	0	.25	.30	.30	.29	.35	.32	.27	.29	.38	.34	.31	.36	.24	.26	.29
11	1.12	.80	1.34	.82	.91	1.15	1.40	1.11	1.38	.85	1.50	.98	1.07	1.39	1.26	1.15	1.33	.91	.98	1.07
18	.10	.15	.15	.15	.14	trace	.12	.15	.14	.15	.10	trace	.12	.10	.10	.11	.08	.08	.09	.08
23	.17	.43	.15	.26	.23	.12	.12	.16	.20	.15	.15	.10	.13	.15	.11	.12	.09	.16	.18	.26
24	.18	.43	.15	.25	.22	.13	.13	.16	.20	.15	.16	.10	.13	.15	.12	.12	.10	.17	.19	.27
Monthly Totals	2.16	2.42	2.24	2.29	2.19	1.94	2.31	2.20	2.53	2.20	2.51	1.88	2.05	2.50	2.15	2.00	2.18	1.78	1.86	2.16
June 7	.60	1.45	.64	.76	.83	.44	.40	.78	.46	.80	.42	.65	.66	.42	.45	.55	.28	.27	.48	.31
22	.45	trace	.25	.10	.09	.98	1.00	.45	1.68	.15	.99	.84	.30	.38	.27	.26	.13	.08	.32	0
26	.06	.04	.15	0	0	.24	.07	0	.21	.05	.21	0	0	.05	0	0	.02	0	0	0
Monthly Totals	1.11	1.49	1.04	0.86	0.92	1.66	1.47	1.23	2.35	1.00	1.62	1.49	0.96	0.85	0.72	0.81	0.43	0.35	0.80	0.31
July 6	.07	0	0	0	0	0	.04	0	0	.03	0	trace	.04	0	trace	.40	0	.43	.12	.45
31	1.11	.55	1.55	.57	.83	2.10	1.39	.95	1.62	.74	1.84	1.10	1.13	1.70	.81	.91	.45	.46	1.54	.72
Monthly Totals	1.18	0.55	1.55	0.57	0.83	2.10	1.43	0.95	1.62	0.77	1.84	1.10	1.17	1.70	0.81	1.31	0.45	0.89	1.66	1.17
Aug. 1	.07	0	.15	.05	0	.21	.14	.04	.16	.06	.18	.04	.05	.07	.03	.04	.02	.02	.06	.03
19	.10	.03	.17	0	0	.12	.08	.37	.23	.07	0	.17	.29	.14	0	.09	0	trace	0	.10
31	.48	.52	1.54	.30	.45	.90	1.23	.25	.53	.62	1.25	.15	.20	.75	.23	.07	.23	.10	.04	.03
Monthly Totals	0.65	0.55	1.86	0.35	0.45	1.23	1.45	0.66	0.92	0.75	1.43	0.36	0.54	0.96	0.26	0.20	0.25	0.12	0.10	0.16
Sept. 4	.02	.03	.02	.02	.02	.10	.06	0	.03	0	0	0	0	0	0	0	0	0	0	0
20	.01	.04	trace	0	0	.03	0	0	0	trace	0	0	trace	0	0	trace	0	0	trace	.03
29	.13	.42	.09	.08	.38	.05	.05	0	.06	.07	.04	0	0	0	.10	.32	.25	.13	.15	0
30	.06	.06	.14	.12	.05	.07	.07	.04	.09	.10	.06	.05	.04	.04	.03	.02	.04	.05	.02	.04
Monthly Totals	0.22	0.55	0.25	0.22	0.45	0.25	0.18	0.04	0.18	0.17	0.10	0.05	0.04	0.04	0.13	0.34	0.29	0.18	0.17	0.07
1954 WATER YEAR TOTALS	15.13	16.10	14.43	14.29	14.71	19.06	17.11	13.62	17.98	16.20	17.07	15.45	13.26	15.71	13.08	12.57	12.94	13.85	14.55	14.41
Oct. 5	.90	1.01	1.57	.96	.92	.80	.76	1.00	.99	.85	.61	1.07	.86	.97	.83	.56	1.01	1.16	.40	.83
27	.82	1.29	1.09	1.04	1.21	.69	.57	.83	.71	.96	.53	.80	.62	.69	.82	.75	.70	.68	.70	.70
Monthly Totals	1.72	2.30	2.66	2.00	2.13	1.49	1.33	1.83	1.70	1.81	1.14	1.87	1.48	1.66	1.65	1.31	1.71	1.84	1.10	1.53
Nov. 3	.12	.11	.23	.13	.09	.26	.26	.20	.17	.15	.11	.17	.16	.03	.04	.05	.03	.03	.04	.05
9	.13	.18	.17	.10	.15	.20	.20	.14	.13	.11	.09	.13	.12	.08	.10	.11	.09	.07	.11	.12
14	.91	1.40	1.44	.78	1.27	1.20	.75	1.44	.72	.55	.68	.75	.58	.50	1.37	.59	.80	.71	.36	.83
Monthly Totals	1.16	1.69	1.84	1.01	1.51	1.66	1.21	1.78	1.02	0.81	0.88	1.05	0.86	0.61	1.51	0.75	0.92	0.81	0.51	1.00

*Recording rain gage at site 11 exchanged with non-recording rain gage at site 19, Nov. 3, 1954.

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number																		
		1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-S	18-S	19-R
1954																				
Dec. 11	0.06	0.20	0.02	0.08	0.09	0.03	0.02	0.02	0.03	0.08	0.08	0.05	0.03	0.06	0.03	0.03	0.03	0.04	0.05	0.15
28	.23	.32	.21	.18	.20	.26	.18	.38	.22	.23	.18	.24	.27	.17	.19	.18	.25	.16	.25	.30
Monthly Totals	0.29	0.52	0.23	0.26	0.29	0.29	0.20	0.40	0.25	0.31	0.26	0.29	0.30	0.23	0.22	0.21	0.28	0.20	0.30	0.45
1955																				
Jan. 5	.03	.04	.04	.03	.06	.05	.02	.04	.01	.10	.03	.03	.01	.02	.01	.01	.06	.02	.01	.03
9	.48	.56	.50	.53	.55	.56	.48	.58	.57	.52	.38	.48	.46	.40	.38	.38	.43	.36	.44	.40
14	.07	.06	.07	.05	.06	.11	.10	.07	.12	.07	.07	.07	.07	.06	.05	.04	.07	.06	.07	.08
14	.05	.10	.02	.05	.10	.04	.04	.07	.04	.06	.03	.06	.07	.03	.03	.02	.03	.03	.04	.04
15	.09	.10	.06	.05	.10	.10	.09	.07	.10	.11	.06	.07	.07	.10	.08	.06	.11	.10	.12	.13
17	.08	.02	.10	.09	.02	.17	.15	.11	.18	.11	.11	.11	.12	.05	.04	.03	.05	.05	.05	.06
Monthly Totals	0.80	0.88	0.79	0.80	0.89	1.03	0.88	0.94	1.02	0.97	0.68	0.82	0.80	0.66	0.59	0.54	0.75	0.62	0.73	0.74
Feb. 3	.08	.19	.04	.11	.14	.05	.05	.11	.05	.12	.04	.11	.12	.04	.05	.04	.05	.04	.03	.05
4	.78	1.09	.69	.67	.78	.80	.80	.68	.88	.76	.71	.70	.77	.74	.77	.77	.79	.74	.59	.85
19	.01	.03	trace	trace	tracw	.03	trace	trace	trace	.03	trace	trace	trace	trace	trace	trace	trace	trace	trace	.03
27	.01	.05	0	0	0	.03	0	0	0	.05	0	0	0	0	0	0	0	0	0	trace
Monthly Totals	0.88	1.36	0.73	0.78	0.92	0.91	0.85	0.79	0.93	0.96	0.75	0.81	0.89	0.78	0.82	0.81	0.84	0.78	0.62	0.93
Mar. 13	.32	.95	.21	.36	.37	.66	.54	.30	.63	.50	.12	.73	.28	trace	trace	trace	trace	trace	trace	trace
18	.26	0	.14	.08	0	.22	.19	.12	.22	.10	.14	.17	.18	.27	.15	.64	.37	.70	.42	1.05
19	.11	.20	.13	.12	.20	.20	.17	.17	.20	.15	.13	.25	.26	0	0	0	0	0	0	0
Monthly Totals	0.69	1.15	0.48	0.56	0.57	1.08	0.90	0.59	1.05	0.75	0.39	1.15	0.72	0.27	0.15	0.64	0.37	0.70	0.42	1.05
Apr. 5	.05	trace	trace	trace	trace	.05	.06	trace	.05	trace	.09	trace	trace	.10	.18	.09	.12	.14	.03	.07
9	.16	.10	.17	.14	.05	.15	.13	.09	.09	.07	.10	.06	.02	.24	.15	.14	.37	.30	.22	.44
11	.32	1.20	.66	.58	.65	.58	.48	.37	.33	.30	.37	.25	.07	0	0	0	0	0	0	0
20	.17	.15	.10	.09	.09	.15	.12	.10	.12	.17	.18	.16	.17	.18	.19	.22	.21	.25	.28	.30
Monthly Totals	0.70	1.45	0.93	0.81	0.79	0.93	0.79	0.56	0.59	0.54	0.74	0.47	0.26	0.52	0.52	0.45	0.70	0.69	0.53	0.81
May 7	.07	.10	.07	.05	.08	.10	.07	.10	.09	.08	.06	.09	.09	.04	.05	.05	.04	.05	.06	.05
8-9	.11	.15	.13	.09	.12	.19	.13	.18	.14	.14	.10	.15	.15	.05	.05	.05	.04	.06	.07	.06
10-11	2.55	1.25	2.63	1.78	.95	3.77	2.72	3.34	2.98	2.63	2.02	2.87	2.82	2.52	2.59	2.58	2.06	2.79	3.32	2.83
11	.58	.38	.52	.45	.40	.60	.55	.39	.72	.34	.44	.47	.49	.67	.64	.93	.73	.81	.68	.74
16-17	.54	.99	.47	.69	1.04	.55	.51	.60	.66	.52	.40	.72	.74	.27	.26	.38	.29	.33	.28	.30
17	1.94	1.75	1.63	2.31	1.83	1.90	1.75	2.01	2.29	1.74	1.40	2.39	2.48	1.74	1.67	2.41	1.85	2.10	1.76	1.91
18-19	.69	.75	.60	.70	.78	.70	.73	.82	.68	.80	.70	.67	.94	.60	.79	.64	.54	.57	.68	.52
26	.19	.20	.18	.12	.15	.23	.20	.19	.24	.19	.15	.19	.18	.14	.18	.18	.20	.22	.17	.30
Monthly Totals	6.67	5.57	6.33	6.19	5.35	8.04	6.66	7.63	7.80	6.44	5.27	7.55	7.89	6.03	6.23	7.22	5.75	6.93	7.02	6.71

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	*17-S	18-S	*19-R
1955																				
June 4	0.98	1.05	1.34	0.85	1.45	1.50	1.30	0.93	1.35	0.95	1.46	0.84	0.76	0.67	0.58	0.82	0.56	0.61	0.78	0.65
5	.08	0	0	0	0	0	0	0	0	0	0	0	0	.21	.18	.25	.17	.19	.24	.20
6	.76	.55	.21	1.03	.76	.23	.20	1.12	.21	1.15	.23	1.01	.93	.98	.85	1.20	.82	.90	1.14	.95
8	.67	.70	.90	.88	1.00	1.03	.82	.85	.91	.70	.88	.58	.44	.71	.57	.31	.51	.31	.25	.15
9	.16	.08	.07	.10	.11	.08	.07	.09	.07	.07	.07	.06	.04	.38	.30	.17	.27	.17	.13	.08
14-15	1.16	1.10	1.55	1.74	1.58	1.76	1.41	1.67	1.56	1.38	1.51	1.14	.87	1.19	.94	.52	.85	.52	.41	.25
15	.14	.10	.10	.13	.09	.10	.11	.05	.08	.08	.17	.06	.12	.06	trace	.29	.12	.36	.36	.40
29	.02	.05	0	.11	.05	trace	.02	0	0	.20	0	0	0	0	0	0	0	trace	0	0
Monthly Totals	3.97	3.63	4.17	4.84	5.04	4.70	3.93	4.71	4.18	4.53	4.32	3.69	3.16	4.20	3.42	3.56	3.30	3.06	3.31	2.68
July 12	.06	.08	.01	0	0	.15	.15	trace	.05	0	.42	.02	.02	.23	.01	0	.01	0	0	.06
15	.31	.10	.14	.52	.10	.10	.14	.56	.13	.49	.15	.56	.56	.38	.36	.35	.40	.40	.23	.40
16-17	2.16	1.36	2.17	2.65	1.41	1.60	2.20	2.84	2.07	2.50	2.44	2.86	2.86	2.30	2.16	2.08	2.41	2.40	1.38	2.40
17-18	1.44	1.55	1.49	1.12	1.61	1.10	1.51	1.20	1.42	1.06	1.68	1.21	1.21	1.71	1.60	1.54	1.78	1.78	1.03	1.78
18	.14	.35	.14	.06	.36	.11	.15	.05	.15	.05	.16	.06	.06	.13	.12	.12	.14	.14	.08	.14
23	.04	.10	trace	.03	.02	.16	0	0	.01	trace	0	0	.01	0	.10	0	0	.16	0	.20
Monthly Totals	4.15	3.54	3.95	4.38	3.50	3.22	4.15	4.65	3.83	4.10	4.85	4.71	4.72	4.75	4.35	4.09	4.74	4.88	2.72	4.98
Aug. 9	.14	0	.49	.42	0	.12	.08	.65	0	.55	.07	.28	.14	0	0	0	0	0	0	0
10	.05	.27	.20	0	0	.05	.04	0	0	0	.03	0	0	.08	0	0	0	.08	0	.14
11	.03	.11	0	.08	0	0	0	.12	0	.10	0	.05	.02	0	0	0	0	0	0	0
12	.07	.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	.35	.12	.63	.42	.16	.36	.26	.34	.34	.40	.12	.46	.70	.14	.20	.74	.26	.31	.72	.20
21	.15	.15	0	.10	.21	0	0	.09	0	.10	0	.12	.17	.09	.14	.50	.17	.21	.50	.13
28	.13	0	0	0	0	0	0	0	0	0	0	0	0	.95	.22	.02	.51	.22	.08	.25
30	.71	.34	1.50	.69	.62	.50	1.09	.20	.38	0	2.54	.17	.13	2.50	.57	.05	1.34	.58	.22	.67
Monthly Totals	1.63	1.93	2.82	1.71	0.99	1.03	1.47	1.40	0.72	1.15	2.76	1.08	1.16	3.76	1.13	1.31	2.28	1.40	1.52	1.39
Sept.10-11	.28	.10	.30	.88	.27	.27	.11	.76	.32	1.00	.06	.38	.05	.26	.27	.06	.11	.04	.10	0
22	2.82	1.97	3.30	3.45	2.60	2.68	2.76	3.31	2.84	2.74	2.51	2.59	2.34	2.77	2.71	3.02	2.62	3.38	3.32	3.33
24	.42	.31	.41	.34	.69	.25	.24	.39	.34	.30	.29	.63	.26	.51	.75	.19	.54	.62	.24	.55
Monthly Totals	3.52	2.38	4.01	4.67	3.56	3.20	3.11	4.46	3.50	4.04	2.86	3.60	2.65	3.54	3.73	3.27	3.27	4.04	3.66	3.88
1955 WATER YEAR TOTALS	26.18	26.40	28.94	28.01	25.54	27.58	25.48	29.74	26.59	26.41	24.90	27.09	24.89	27.01	24.32	24.16	24.91	25.95	22.44	26.15
Oct. 5	.03	trace	trace	.01	.03	trace	.01	trace	trace	trace	trace	trace	trace	.01	.01	.01	.10	.15	.13	.08
6	.01	trace	0	0	0	.12	0	0	trace	0	0	0	0	0	0	trace	0	trace	0	0
Monthly Totals	0.04	trace	trace	0.01	0.03	0.12	0.01	trace	trace	trace	trace	trace	trace	0.01	0.01	0.01	0.10	0.15	0.13	0.08

*Non-recording rain gage at site 17 exchanged with recording rain gage at site 19, June 29, 1955.

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

		Gage Number																			
Date of storm	Storm WMR	1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1955 Nov 30	0.51	0.56	0.60	0.40	0.51	0.52	0.41	0.50	0.57	0.50	0.50	0.57	0.53	0.51	0.40	0.55	0.52	0.45	0.53	0.50
Monthly Totals	0.51	0.56	0.60	0.40	0.51	0.52	0.41	0.50	0.57	0.50	0.50	0.57	0.53	0.51	0.40	0.55	0.52	0.45	0.53	0.50
Dec.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Totals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1956 Jan. 17	.88	1.08	1.00	1.10	1.12	.78	.83	.94	.80	.86	.93	.85	.72	.91	.80	.73	.94	.73	.80	.81
21	.56	.56	.50	.37	.55	.49	.79	.51	.68	.32	.78	.60	.46	.70	.59	.56	.62	.53	.42	.57
Monthly Totals	1.44	1.64	1.50	1.47	1.67	1.27	1.62	1.45	1.48	1.18	1.71	1.45	1.18	1.61	1.39	1.29	1.56	1.26	1.22	1.38
Feb. 1	.06	.05	.07	.06	.07	.05	.08	.08	.10	.04	.04	.09	.05	.07	.07	.05	.04	.04	.06	.07
2	.10	.12	.15	.11	.10	.08	.07	.14	.08	.16	.06	.11	.10	.08	.11	.10	.08	.10	.10	.10
8	.29	.43	.50	.29	.34	.26	.24	.37	.26	.41	.20	.27	.27	.21	.27	.26	.21	.25	.24	.26
9	.16	.20	.15	.16	.19	.11	.18	.16	.18	.14	.14	.14	.17	.16	.14	.16	.17	.13	.19	.16
16	.03	.15	.06	.07	.09	0	.03	.07	.03	0	trace	.02	trace	trace	trace	trace	trace	0	trace	trace
Monthly Totals	0.64	0.95	0.93	0.69	0.79	0.50	0.60	0.82	0.65	0.75	0.44	0.63	0.59	0.52	0.59	0.57	0.50	0.52	0.59	0.59
Mar. 12	.04	.01	.04	.03	.03	.03	.04	.07	.05	.02	.03	.05	.03	.05	.05	.03	.06	.02	.05	.04
21	.02	.03	.02	.04	.05	trace	.01	.02	.03	.02	.01	.02	.02	.01	trace	.02	trace	trace	.03	.01
Monthly Totals	0.06	0.04	0.06	0.07	0.08	0.03	0.05	0.09	0.08	0.04	0.04	0.07	0.05	0.06	0.05	0.05	0.06	0.02	0.08	0.05
Apr. 5	.23	.55	.60	.49	.37	.17	.15	.44	.20	.37	.10	.15	.15	.11	.07	.06	.08	.10	.11	.06
20	.17	.05	.13	.21	.08	.12	.16	.24	.17	.21	.16	.25	.23	.20	.19	.20	.17	.15	.18	.20
21	.48	.34	.46	.40	.54	.43	.57	.46	.59	.39	.58	.47	.42	.55	.51	.55	.46	.41	.48	.55
29	.25	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.87	.77	.57	.60	.50	.41	.43
30	.67	.58	.55	.69	.37	.63	.70	.72	.64	.75	.60	.71	.66	1.05	.92	.69	.73	.60	.49	.51
Apr. 30-May 1	4.85	9.48	5.28	4.65	6.10	6.00	6.63	4.82	6.10	5.04	5.67	4.81	4.43	4.37	3.84	2.86	3.02	2.50	2.05	2.14
Monthly Totals	6.65	11.03	7.05	6.47	7.49	7.38	8.24	6.71	7.73	6.79	7.14	6.42	5.92	7.15	6.30	4.93	5.06	4.26	3.72	3.89
May 1	.09	0	.07	.06	.07	.05	.07	.10	.05	.05	.05	.10	.10	.03	.04	.24	.04	.10	.24	.24
14	.38	.75	.55	.67	.72	.24	.44	.31	.35	.43	.38	.32	.26	.31	.29	.30	.22	.14	.23	.19
23-24	.82	.53	.72	.71	.90	.19	.66	.87	.57	.90	.78	.80	1.06	.89	.94	.90	.94	1.44	1.15	1.19
Monthly Totals	1.29	1.28	1.34	1.44	1.69	0.48	1.17	1.28	0.97	1.38	1.21	1.22	1.42	1.23	1.27	1.44	1.20	1.68	1.62	1.62
June 9	.16	0	0	0	0	0	.61	0	.14	0	.80	trace	trace	.60	.43	.10	.27	0	.18	.16
19	.01	.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Totals	0.17	0.20	0	0	0	0	0.61	0	0.14	0	0.80	trace	trace	0.60	0.43	0.10	0.27	0	0.18	0.16

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number																		
		1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1956																				
July 2	0.05	0.02	0	0.01	0.03	trace	0.02	trace	trace	0.02	0.01	trace	0.23	trace	0	0.28	trace	0.06	0.24	0.06
4	.04	.22	0	.10	.27	0	0	0	0	.12	0	0	trace	0	0	.02	0	0	.05	0
Monthly Totals	0.09	0.24	0	0.11	0.30	trace	0.02	trace	trace	0.14	0.01	trace	0.23	trace	0	0.30	trace	0.06	0.29	0.06
Aug. 19	.69	.13	.03	.66	1.25	.74	1.18	.27	.97	.90	1.22	.72	.53	1.00	1.50	.65	.50	.20	.30	.22
28	.67	.30	.83	.20	.20	.92	1.30	.32	1.06	.12	.84	.98	1.04	.57	.75	1.05	.76	.67	.50	.36
Monthly Totals	1.36	0.43	0.86	0.86	1.45	1.66	2.48	0.59	2.03	1.02	2.06	1.70	1.57	1.57	2.25	1.70	1.26	0.87	0.80	0.58
Sept. 6	.45	.19	.15	.11	.17	.10	.32	.26	.51	.22	.59	.20	.36	.76	.79	1.18	.68	.42	1.06	.30
26	.14	0	.55	.60	.32	.01	0	.43	0	.33	0	.10	.24	.01	.04	.06	.05	trace	.21	.08
Monthly Totals	0.59	0.19	0.70	0.71	0.49	0.11	0.32	0.69	0.51	0.55	0.59	0.30	0.60	0.77	0.83	1.24	0.73	0.42	1.27	0.38
1956 WATER YEAR TOTALS	12.84	16.56	13.04	12.23	14.50	12.07	15.53	12.13	14.16	12.35	14.50	12.36	12.09	14.03	13.52	12.18	11.26	9.69	10.43	9.29
Oct. 15	.69	.70	.81	.95	.65	.72	.59	.83	.70	.67	.89	.56	.51	.67	.57	.58	.61	.64	.77	.84
18	.96	.82	.69	.87	.83	.75	1.02	1.04	.92	1.04	1.01	1.05	1.01	1.12	1.05	1.08	.96	.98	1.04	1.02
30	.77	.52	.68	.75	.62	.70	.58	.68	1.58	.75	.55	.62	1.60	1.63	.65	.65	.54	.53	.61	.55
Monthly Totals	2.42	2.04	2.18	2.57	2.10	2.17	2.19	2.55	3.20	2.46	2.45	2.23	3.12	3.42	2.27	2.31	2.11	2.15	2.42	2.41
Nov. 2	.31	.16	.38	.13	.17	.35	.32	.15	.31	.13	.30	.14	.13	.46	.48	.49	.44	.35	.56	.39
4	.55	.77	.60	.78	.83	.55	.50	.88	.49	.75	.48	.79	.74	.35	.35	.37	.33	.26	.42	.29
Monthly Totals	0.86	0.93	0.98	0.91	1.00	0.90	0.82	1.03	0.80	0.88	0.78	0.93	0.87	0.81	0.83	0.86	0.77	0.61	0.98	0.68
Dec. 6	.20	.49	.35	.25	.41	.10	.36	.25	.22	.16	.15	.11	.17	.17	.24	.12	.03	.05	.07	.03
18-19	1.06	1.15	1.05	.82	.98	1.13	1.17	1.07	1.18	.94	1.08	.95	.92	1.15	1.13	.99	1.09	1.05	1.06	1.05
Monthly Totals	1.26	1.64	1.40	1.07	1.39	1.23	1.53	1.32	1.40	1.10	1.23	1.06	1.09	1.32	1.37	1.11	1.12	1.10	1.13	1.08
1957																				
Jan. 3	.12	.12	.10	.10	.10	.13	.11	.12	.13	.12	.15	.10	.11	.15	.12	.12	.17	.12	.12	.13
23	.11	.08	.10	.09	.09	.10	.10	.09	.11	.08	.11	.10	.14	.14	.13	.12	.13	.12	.14	.14
25	.11	.10	.09	.09	.11	.10	.09	.08	.10	.08	.11	.09	.13	.13	.12	.11	.13	.12	.13	.13
30	.04	.05	.06	.05	.05	.04	.05	.05	.05	.04	.04	.04	.04	.04	.04	.03	.03	.02	.03	.02
31	.30	.39	.40	.38	.41	.27	.33	.36	.36	.31	.29	.30	.31	.29	.27	.26	.20	.15	.23	.17
Monthly Totals	0.68	0.74	0.75	0.71	0.76	0.64	0.68	0.70	0.79	0.63	0.70	0.63	0.73	0.75	0.68	0.64	0.66	0.53	0.65	0.59

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number																		
		1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1957																				
Feb. 13	0.06	0.02	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.10	0.10	0.12	0.11	0.10	0.12	0.12
16	.46	.45	.65	.60	.55	.55	.56	.53	.60	.55	.54	.50	.51	.30	.31	.37	.32	.30	.35	.36
17	.30	.30	.30	.33	.37	.25	.25	.29	.27	.30	.24	.27	.28	.28	.29	.35	.30	.28	.33	.34
19	.07	.09	.02	.07	.11	.02	.02	.07	.02	.07	.02	.06	.06	.10	.09	.12	.10	.09	.10	.11
22	.15	.05	.11	.08	.12	.10	.12	.08	.18	.08	.20	.09	.13	.20	.19	.16	.34	.17	.19	.25
Monthly Totals	1.04	0.91	1.12	1.11	1.17	0.95	0.98	1.00	1.10	1.03	1.03	0.95	1.01	0.98	0.98	1.12	1.17	0.94	1.09	1.18
Mar. 10	.51	.42	.39	.40	.43	.47	.46	.38	.49	.39	.56	.44	.57	.61	.57	.68	.58	.60	.64	.59
17	.01	0	0	.01	.01	0	.01	trace	.02	0	.02	.01	.02	.02	.03	.02	.03	trace	.06	.03
20	.12	.05	.15	.10	.04	.14	.21	.10	.20	.10	.25	.11	.12	.11	.12	.11	.10	.10	.12	.10
20	1.02	.89	.67	.73	.68	.65	.96	.71	.91	.75	1.18	.84	.99	1.36	1.53	1.32	1.22	1.22	1.53	1.24
31	.21	.09	.20	.25	.26	.20	.19	.22	.22	.17	.21	.21	.22	.25	.22	.21	.22	.17	.22	.26
Monthly Totals	1.87	1.45	1.41	1.49	1.42	1.46	1.83	1.41	1.84	1.41	2.22	1.61	1.92	2.35	2.47	2.34	2.15	2.09	2.57	2.22
Apr. 3	.33	.70	.37	.52	.57	.25	.32	.35	.27	.38	.36	.32	.33	.31	.25	.23	.21	.01	.24	.18
12-13	.10	.04	.17	.10	.12	.03	.18	.09	.18	.06	.12	.12	.13	.15	.13	.09	.08	.03	.08	.09
18-19	1.84	1.35	2.04	1.92	1.73	2.10	1.95	2.13	2.22	2.10	1.95	2.08	2.10	1.64	1.63	1.94	1.56	1.56	1.64	1.48
22-23	1.18	1.18	1.03	1.12	1.52	1.06	.99	1.24	1.13	1.22	.98	1.20	1.22	1.19	1.18	1.40	1.13	1.13	1.19	1.07
24	.14	.10	.14	.09	.12	.15	.13	.09	.15	.10	.09	.09	.08	.19	.21	.20	.15	.16	.17	.13
26	3.19	3.70	3.96	4.14	4.27	4.10	3.45	4.15	4.03	4.54	2.36	4.03	3.64	2.22	2.36	2.32	1.73	1.84	1.91	1.48
28-29	.39	.13	.32	.24	.15	.33	.27	.24	.32	.26	.18	.23	.21	.69	.76	.72	.54	.57	.58	.45
29	.09	0	0	0	0	0	0	0	0	0	0	0	0	.20	.35	.27	.25	.19	.22	.15
30	.20	.10	.76	.15	.12	.40	.32	.25	.68	.17	.38	.38	.27	0	0	0	0	0	0	0
Monthly Totals	7.46	7.30	8.79	8.28	8.60	8.42	7.61	8.54	8.98	8.83	6.42	8.45	7.98	6.59	6.87	7.17	5.65	5.49	6.03	5.03
May 3	.14	.14	.13	.19	.17	.07	.06	.32	.12	.22	.07	.49	.35	.05	.09	.07	.07	.05	.06	.04
4	.41	.22	.43	.32	.27	.22	.18	.51	.37	.36	.21	.79	.56	.40	.68	.53	.49	.38	.43	.31
9	.71	1.00	.65	.71	.71	.71	.81	.77	.76	.75	.84	.81	.90	.62	.58	.58	.57	.55	.58	.51
11	1.51	1.00	1.29	.85	.71	1.42	1.61	.92	1.52	.90	1.67	.98	1.09	2.26	2.12	2.12	2.07	2.00	2.10	1.85
12	.43	1.47	.27	.40	1.04	.30	.34	.43	.32	.42	.35	.46	.51	.23	.21	.21	.21	.20	.21	.18
13	.79	.91	.65	.75	.63	.72	.81	.82	.78	.81	.85	.87	.97	.85	.81	.80	.77	.75	.78	.70
17	1.31	1.38	1.20	1.44	1.45	1.38	1.51	1.47	1.46	1.27	1.27	1.19	1.21	1.29	1.37	1.19	1.19	1.14	1.22	1.01
18	.76	.71	.73	.75	.75	.83	.91	.76	.87	.66	.76	.62	.62	.82	.87	.75	.76	.72	.77	.64
23	1.11	1.75	1.47	1.88	2.04	1.10	1.01	1.45	.98	1.75	.71	1.18	.96	.75	.73	.70	.67	.65	.64	.60
25	.07	.20	.11	.12	.23	.08	.07	.09	.07	.11	.05	.07	.06	0	0	0	0	0	0	0
26	.11	.06	.07	.13	.07	.05	.05	.10	.04	.12	.03	.09	.07	.20	.19	.18	.18	.17	.17	.16
31	.23	.23	0	.23	.20	0	0	.23	0	.23	0	.24	.27	.48	.46	.33	.49	.30	.27	.41
Monthly Totals	7.58	9.07	7.00	7.77	8.27	6.88	7.36	7.87	7.29	7.60	6.81	7.79	7.57	7.95	8.11	7.46	7.47	6.91	7.23	6.41

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1957																				
June 1	0.63	0.23	0.69	0.51	0.20	0.73	0.73	0.51	0.83	0.52	0.80	0.55	0.63	0.89	0.85	0.60	0.91	0.55	0.53	0.74
1	.13	.40	.10	.20	.35	.12	.12	.20	.14	.20	.13	.21	.24	0	0	0	0	0	0	0
2	.07	.29	.09	.07	.25	.08	.08	.07	.08	.08	.08	.08	.09	0	0	0	0	0	0	0
5	.43	.10	.12	.16	.35	.92	.46	1.05	.42	.05	.42	.58	.32	.79	.41	.24	.62	.30	.24	.11
12	.96	1.00	.86	1.15	2.13	.96	.88	.99	.76	2.27	.84	.68	.84	.95	.74	.72	.70	.56	.60	.67
Monthly Totals	2.22	2.02	1.86	2.09	3.28	2.81	2.27	2.82	2.28	3.12	2.27	2.10	2.12	2.63	2.00	1.56	2.23	1.41	1.37	1.52
July 9	.18	.14	.21	.22	.36	.15	.34	.38	.18	.50	.30	.30	.02	0	.37	.01	.02	0	0	0
21	.14	0	0	0	0	0	0	0	0	0	0	0	0	.25	.14	.14	.77	.50	.41	.62
22	.12	.05	.18	.07	.04	.30	.43	.06	.16	.04	.37	.06	.06	.05	.03	.03	.16	.10	.08	.13
23	.60	.60	.13	.23	.51	.22	.32	.21	.11	.13	.28	.21	.20	.74	.40	.40	2.29	1.48	1.21	1.82
26	.08	.36	.19	.28	.11	0	0	.20	0	.25	0	.12	.01	0	0	0	0	0	0	0
Monthly Totals	1.12	1.15	0.71	0.80	1.02	0.67	1.09	0.85	0.45	0.92	0.95	0.69	0.29	1.04	0.94	0.58	3.24	2.08	1.70	2.57
Aug. 2	.06	0	.02	.02	0	.28	.19	.02	.25	.13	.03	.11	.07	0	0	0	0	0	0	0
5	.46	.48	.03	.31	.29	.65	.43	.22	.58	1.60	.08	1.37	.89	.19	.44	.70	.06	.10	.05	.20
Monthly Totals	0.52	0.48	0.05	0.33	0.29	0.93	0.62	0.24	0.83	1.73	0.11	1.48	0.96	0.19	0.44	0.70	0.06	0.10	0.05	0.20
Sept. 3	.36	.47	.14	.18	.28	.07	.14	.17	.15	.49	.17	.18	.58	.32	.23	.80	.67	.67	.43	.81
7	.13	0	.02	.14	.44	0	.03	.02	.01	.18	.01	.05	.09	.02	.02	.63	.01	0	.55	.18
11	.73	2.07	1.05	.95	1.39	.61	.62	.45	.64	.46	.57	.35	.46	.66	.56	.47	.57	.36	.34	.50
21	.31	.31	.30	.26	.30	.36	.25	.41	.30	.22	.35	.30	.32	.35	.35	.28	.35	.29	.24	.35
25	.04	0	.12	.07	.07	0	.10	.12	.12	.07	0	.13	.07	0	0	.03	0	0	0	0
Monthly Totals	1.57	2.85	1.63	1.60	2.48	1.04	1.14	1.17	1.22	1.42	1.10	1.01	1.52	1.35	1.16	2.21	1.60	1.32	1.56	1.84
1957 WATER YEAR TOTALS	28.60	30.58	27.88	28.73	31.68	28.10	28.12	29.55	30.13	31.00	26.07	28.93	29.18	29.38	28.12	28.06	28.23	24.73	26.80	25.78
Oct. 8	.04	.04	trace	trace	.02	trace	0	.01	trace	0	.04	trace	.20	.09	.04	.05	.14	.02	0	.05
13	1.51	.75	1.15	1.27	.82	1.34	1.42	1.28	1.36	1.33	1.73	1.44	1.37	1.88	1.63	1.74	2.24	2.03	1.88	2.45
14	1.07	1.17	.83	.92	1.28	.97	1.03	.94	.99	.97	1.26	1.05	1.00	1.10	.94	1.00	1.29	1.17	1.10	1.41
15	.49	.57	.39	.42	.63	.45	.48	.42	.46	.44	.58	.47	.45	.46	.41	.44	.57	.51	.46	.62
21-22	.27	.40	.30	.34	.40	.22	.25	.27	.27	.29	.22	.29	.25	.27	.22	.23	.17	.24	.21	.30
22	.12	0	.09	.08	0	.10	.08	.11	.09	0	.09	.09	.14	.11	.12	.25	.24	.22	.17	.32
Monthly Totals	3.50	2.93	2.76	3.03	3.15	3.08	3.26	3.03	3.17	3.03	3.92	3.34	3.41	3.91	3.36	3.71	4.65	4.19	3.82	5.15

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1957 Nov. 2	0.08	0	0.09	0.08	0	0.07	0.06	0.08	0.07	0.08	0.06	0.06	0.06	0.15	0.15	0.13	0.11	0.10	0.09	0.10
3	.30	.25	.59	.46	.27	.48	.44	.47	.45	.48	.41	.36	.33	.15	.15	.13	.11	.10	.09	.10
3-4	.13	.25	.14	.21	.27	.11	.10	.22	.10	.22	.09	.16	.15	.07	.07	.06	.05	.05	.05	.05
5	.76	.85	.96	.83	.90	.78	.72	.85	.74	.87	.67	.65	.60	.90	.90	.78	.67	.57	.52	.53
6	.04	.25	0	.03	.21	0	0	.03	0	.03	0	.03	.03	0	0	0	0	0	0	0
7	.09	.07	.06	.12	.06	.05	.05	.10	.05	.10	.05	.11	.11	.11	.10	.12	.10	.10	.09	.12
8	.02	0	.06	.05	0	.05	.05	.04	.05	.04	.05	.04	.04	0	0	0	0	0	0	0
9	.32	.37	.36	.38	.31	.30	.31	.34	.32	.33	.30	.35	.35	.30	.29	.33	.28	.28	.26	.33
10-11	.26	.32	.28	.27	.27	.23	.25	.24	.25	.23	.23	.25	.24	.27	.25	.27	.25	.24	.22	.27
18	.07	.05	.06	.08	.09	.05	.07	.07	.09	.05	.08	.08	.09	.07	.07	.08	.08	.07	.04	.11
21	.11	.05	.08	.13	.05	.08	.08	.17	.09	.15	.09	.15	.13	.13	.13	.11	.12	.13	.13	.13
23	.06	.10	.07	.04	.10	.07	.07	.06	.08	.05	.08	.05	.04	.02	.02	.02	.02	.02	.02	.02
24	.97	.95	.91	.81	.96	.92	.96	1.06	1.00	.96	.97	.95	.85	1.07	1.06	.86	1.00	1.04	1.05	1.08
Monthly Totals	3.21	3.51	3.66	3.49	3.49	3.19	3.16	3.73	3.29	3.59	3.08	3.24	3.02	3.24	3.19	2.89	2.79	2.70	2.56	2.84
Dec. 6	.32	.26	.27	.29	.25	.30	.34	.30	.36	.35	.33	.34	.33	.38	.34	.34	.37	.42	.21	.38
24-25	.95	.83	.92	1.01	.96	.94	1.19	1.06	1.25	.91	1.01	1.01	.97	1.05	.97	.98	.76	.81	.75	.75
Monthly Totals	1.27	1.09	1.19	1.30	1.21	1.24	1.53	1.36	1.61	1.26	1.34	1.35	1.30	1.43	1.31	1.32	1.13	1.23	0.96	1.13
1958 Jan. 4-5	.67	.53	.65	.66	.69	.61	.67	.60	.86	.60	.59	.56	.60	.76	.71	.76	.59	.70	.74	.78
12	.23	.06	.10	.11	.12	.17	.38	.20	.25	.16	.45	.17	.26	.30	.35	.17	.42	.35	.20	.40
18	.11	.05	.13	.10	.06	.12	.16	.11	.19	.10	.15	.11	.12	.11	.10	.11	.09	.10	.12	.10
19	.27	.15	.32	.20	.18	.30	.40	.22	.48	.20	.37	.22	.24	.27	.26	.29	.23	.25	.29	.26
22-23	.76	.71	.49	.68	.86	.44	.58	.73	.71	.69	.53	.74	.87	.92	.91	1.00	.79	.87	1.00	.90
Monthly Totals	2.04	1.50	1.69	1.75	1.91	1.64	2.19	1.86	2.49	1.75	2.09	1.80	2.09	2.36	2.33	2.33	2.12	2.27	2.35	2.44
Feb. 5	.01	trace	.02	.02	trace	trace	trace	trace	.05	trace	.03	trace	trace	.03	trace	trace	trace	trace	trace	.02
9-12	.09	.05	.09	.06	.14	.05	.09	.07	.15	.05	.07	.10	.07	.17	.13	.07	.14	.06	.12	.09
14	.01	trace	.02	.03	.03	trace	.02	trace	.04	trace	.02	.04	.02	.02	.02	trace	trace	0	trace	trace
20	.15	.15	.11	0	.17	.10	.10	0	.11	0	.10	0	0	.26	.27	.28	.23	.28	.29	.31
21	.14	.15	.19	.10	.17	.18	.18	.11	.20	.11	.17	.11	.12	.11	.12	.12	.10	.12	.13	.13
21	.59	.50	.53	.56	.56	.50	.51	.58	.55	.59	.48	.60	.64	.63	.65	.67	.56	.68	.71	.75
22	1.58	1.55	1.50	1.63	1.73	1.43	1.46	1.69	1.57	1.73	1.38	1.74	1.89	1.49	1.54	1.57	1.33	1.61	1.69	1.76
Monthly Totals	2.57	2.40	2.46	2.40	2.80	2.26	2.36	2.45	2.67	2.48	2.25	2.59	2.74	2.71	2.73	2.71	2.36	2.75	2.94	3.06

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1958																				
Mar. 1	0.31	0.30	0.33	0.27	0.29	0.30	0.29	0.31	0.33	0.25	0.27	0.25	0.24	0.36	0.35	0.38	0.36	0.30	0.33	0.36
4	.17	.13	.27	.09	.13	.25	.24	.10	.27	.08	.23	.08	.08	.20	.19	.20	.19	.16	.17	.20
5	.12	.40	.06	.23	.38	.05	.05	.26	.05	.21	.04	.22	.19	0	0	0	0	0	0	0
6	.67	.20	.54	.44	.40	.55	.76	.60	.81	.60	1.02	.87	.91	.84	.80	.61	.71	.80	.76	.83
8	.16	.05	.09	.14	.10	.09	.12	.20	.13	.20	.17	.29	.30	.19	.18	.14	.16	.18	.17	.19
12	.48	.17	.42	.36	.35	.28	.54	.51	.58	.45	.56	.53	.52	.57	.57	.56	.63	.52	.61	.60
18	.06	.30	.14	0	.29	.10	.06	0	.09	0	.09	0	0	0	0	0	0	0	0	0
22	.30	.50	.60	.66	.48	.44	.28	.62	.41	.45	.40	.50	.45	0	0	0	0	0	0	0
25	.20	.06	.06	.15	.06	.05	.04	.14	.05	.10	.04	.11	.10	.44	.46	.43	.33	.35	.45	.33
28	.02	0	.02	.02	trace	0	0	.02	.05	0	.03	.04	.03	.03	.04	.03	.02	0	.02	.01
Monthly Totals	2.49	2.08	2.53	2.36	2.48	2.11	2.38	2.76	2.77	2.34	2.85	2.89	2.82	2.63	2.59	2.35	2.40	2.31	2.51	2.52
Apr. 8	.28	.13	.40	.18	.13	.95	.44	.21	.41	.06	.51	.26	.13	.55	.14	.13	.17	.14	.07	.17
13	1.07	.85	.97	.86	.86	.95	1.20	1.00	1.46	.95	1.22	.98	1.08	1.28	1.33	1.19	1.08	1.15	.98	.87
17	.23	.25	.35	.33	.29	.25	.20	.31	.18	.25	.14	.25	.25	.15	.16	.23	.18	.17	.22	.20
18	.11	.25	.32	.13	.29	.23	.18	.13	.17	.10	.13	.10	.10	0	0	0	0	0	0	0
20	.81	.94	1.04	1.09	1.11	.75	.58	1.04	.54	.83	.43	.84	.81	.63	.64	.96	.73	.70	.89	.84
25-29	.05	.07	.12	.10	.11	.03	.04	.05	.03	.03	.06	.06	.05	.01	.02	.04	.03	trace	.05	.05
30	.36	0	.45	.25	0	.50	.52	.26	.60	.23	.48	.29	.33	.46	.41	.49	.33	.37	.42	.52
Monthly Totals	2.91	2.49	3.65	2.94	2.79	3.66	3.16	3.00	3.39	2.45	2.97	2.78	2.75	3.08	2.70	3.04	2.52	2.53	2.63	2.65
May 2	.23	0	.18	.46	0	.20	.20	.48	.24	.42	.19	.54	.60	.19	.17	.20	.14	.15	.17	.21
2	.75	1.52	.44	.51	1.57	.48	.51	.55	.58	.47	.47	.60	.66	.82	.74	.90	.60	.67	.76	.95
9	.09	.25	.28	0	.20	.21	.23	0	.21	0	.24	0	0	0	0	0	0	0	0	0
11	.12	.61	0	.26	.49	0	0	.19	0	.21	0	.15	.15	0	0	0	0	0	0	0
13	1.22	1.54	1.58	1.74	1.22	1.17	1.30	1.31	1.19	1.43	1.32	1.03	1.03	1.31	1.00	1.02	1.28	.75	1.13	.85
14	.11	.05	.07	.17	.04	.05	.06	.15	.06	.16	.05	.09	.11	.14	.10	.14	.14	.15	.19	.24
16	.20	.18	.45	.24	.25	.05	.07	.27	.28	.30	.29	.10	.18	.10	.08	.16	.13	.20	.26	.39
Monthly Totals	2.72	4.15	3.00	3.38	3.77	2.16	2.37	2.95	2.56	2.99	2.56	2.51	2.73	2.56	2.09	2.42	2.29	1.92	2.51	2.64
June 8	.05	0	.04	.01	trace	.25	.26	.04	.17	0	.14	.03	0	.02	0	0	0	0	0	0
16	.27	.26	.23	.28	.38	.23	.23	.30	.32	.26	.24	.34	.24	.21	.24	.31	.24	.20	.26	.23
21	2.00	2.15	2.27	2.17	1.97	2.31	2.56	2.10	2.36	2.20	2.59	1.91	1.60	2.24	2.01	1.60	1.63	1.88	1.16	1.06
Monthly Totals	2.32	2.41	2.54	2.46	2.35	2.79	3.05	2.44	2.85	2.46	2.97	2.28	1.84	2.47	2.25	1.91	1.87	2.08	1.42	1.29
July 6	.12	.04	.06	.18	.06	.05	.21	.04	.10	.05	.25	.02	.05	.31	.30	.05	.28	.06	.05	.04
20	.10	.25	0	.24	.30	0	0	.18	0	.25	0	.26	.50	0	0	0	0	0	0	0
22	.38	.22	.33	.17	.27	.36	.49	.13	.42	.18	.59	.18	.36	.40	.28	.95	.44	.25	.77	.38
Monthly Totals	0.60	0.51	0.39	0.59	0.63	0.41	0.70	0.35	0.52	0.48	0.84	0.46	0.91	0.71	0.58	1.00	0.72	0.31	0.82	0.42

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1958 Aug. 10	0.07	0	0.05	0.05	0.04	0	0.02	0.15	0.06	0.16	trace	0.17	0.12	0.02	0.09	0.10	0.10	trace	0.06	0.15
17	.13	.35	.06	.13	.08	trace	.54	.07	.15	0	.32	0	0	.33	0	.06	.08	0	.10	.15
23-24	2.33	1.55	1.89	2.95	2.40	3.80	2.31	3.87	3.29	2.97	2.76	2.73	2.31	2.09	2.24	1.92	.92	1.22	1.48	1.18
Monthly Totals	2.53	1.90	2.00	3.13	2.52	3.80	2.87	4.09	3.50	3.13	3.08	2.90	2.43	2.44	2.33	2.08	1.10	1.22	1.64	1.48
Sept. 6	.43	.92	.95	.39	.41	.63	.50	.19	.30	.20	.25	.18	.20	.28	.24	.38	.34	.33	.50	.84
7	.26	.55	.39	.46	.25	.26	.20	.23	.13	.24	.10	.22	.25	.17	.15	.23	.21	.20	.30	.51
15-16	.66	1.35	.56	.51	1.20	.53	.28	.76	.48	.80	.20	.57	.63	.24	.36	1.00	.27	.45	1.43	.53
16	.11	.05	0	.33	.05	0	0	.51	0	.53	0	.38	.42	0	0	0	0	0	0	0
19	.53	.80	.52	.60	.48	.40	.18	.55	.42	.52	.78	.50	.66	.52	.47	.60	.43	.50	.58	.52
25	.22	1.05	.06	.17	.37	0	trace	.15	.02	.05	.02	.20	.34	.04	.20	.21	.05	.56	.19	.10
26	.02	.19	0	0	.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monthly Totals	2.23	4.91	2.48	2.46	2.83	1.82	1.16	2.39	1.35	2.34	1.35	2.05	2.50	1.25	1.42	2.42	1.30	2.04	3.00	2.50
1958 WATER YEAR TOTALS	28.39	29.91	28.35	29.29	29.93	28.26	28.19	30.41	30.17	28.30	29.30	28.19	28.54	28.79	26.88	28.18	25.25	25.55	27.16	28.22
Oct. 3	.37	.56	.47	.41	.41	.27	.33	.38	.39	.36	.39	.31	.33	.40	.38	.36	.27	.32	.27	.28
12	.31	.39	0	.36	.30	0	0	.25	0	.30	0	.28	.28	.47	.68	.48	.51	.50	.43	.47
14	.23	.43	.43	.27	.34	.25	.32	.20	.42	.23	.28	.21	.22	.10	.14	.10	.10	.10	.09	.09
21	.01	.08	trace	trace	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	.12	.35	0	.18	.29	0	0	.15	0	.15	0	.14	.12	.14	.13	.15	.11	.10	.15	.17
28-29	.35	.36	.68	.39	.30	.33	.50	.34	.51	.33	.39	.32	.27	.27	.25	.30	.23	.30	.29	.34
Monthly Totals	1.39	2.17	1.58	1.61	1.64	0.85	1.15	1.32	1.32	1.37	1.06	1.26	1.22	1.38	1.60	1.39	1.22	1.32	1.23	1.38
Nov. 14	.84	.63	.74	.73	.62	.89	.74	.99	.89	.81	.77	.96	.81	.96	.98	1.04	.80	.72	1.07	.75
17	.14	.21	.26	.15	.20	.31	.26	.21	.31	.17	.27	.20	.16	0	0	0	0	0	0	0
27	.15	.10	.15	.14	.14	.19	.20	.15	.21	.12	.13	.20	.19	.13	.13	.14	.12	.10	.11	.11
Monthly Totals	1.13	0.94	1.15	1.02	0.96	1.39	1.20	1.35	1.41	1.10	1.17	1.36	1.16	1.09	1.11	1.18	0.92	0.82	1.18	0.86
Dec. 1	.14	.10	.14	.14	.13	.18	.20	.14	.21	.12	.12	.20	.19	.12	.13	.13	.11	.10	.11	.10
29	.26	.25	.22	.32	.31	.15	.28	.28	.25	.31	.22	.23	.21	.32	.25	.23	.35	.32	.24	.35
Monthly Totals	0.40	0.35	0.36	0.46	0.44	0.33	0.48	0.42	0.46	0.43	0.33	0.43	0.40	0.44	0.38	0.36	0.46	0.42	0.35	0.45
1959 Jan. 24	trace	0	0	trace	trace	0	0	trace	trace	trace	0	0	0	0	0	0	0	0	0	0
Monthly Totals	trace	0	0	trace	trace	0	0	trace	trace	trace	0	0	0	0	0	0	0	0	0	0

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1959																				
Feb. 1-2	0.27	0.27	0.30	0.34	0.25	0.31	0.24	0.25	0.22	0.27	0.27	0.19	0.20	0.31	0.27	0.22	0.34	0.30	0.30	0.30
13	.26	.36	.25	.21	.23	.33	.23	.31	.25	.28	.23	.10	.22	.24	.24	.27	.27	.32	.26	.33
19	.10	.05	.10	.08	.08	.08	.12	.10	.11	.07	.11	.09	.08	.15	.14	.13	.15	.08	.13	.14
20	.23	.17	.24	.23	.29	.20	.30	.27	.29	.20	.27	.25	.23	.25	.24	.21	.24	.13	.22	.23
Monthly Totals	0.86	0.85	0.89	0.86	0.85	0.92	0.89	0.93	0.87	0.82	0.88	0.63	0.73	0.95	0.89	0.83	1.00	0.83	0.91	1.00
Mar. 4	.22	.49	.25	.22	.27	.18	.23	.22	.20	.10	.21	.23	.23	.27	.25	.20	.16	.13	.07	.06
28	.03	trace	trace	trace	.02	.02	.04	.02	.06	.03	.06	.02	.02	.04	.04	.03	.06	.02	.03	.04
Monthly Totals	0.25	0.49	0.25	0.22	0.29	0.20	0.27	0.24	0.26	0.13	0.27	0.25	0.25	0.31	0.29	0.23	0.22	0.15	0.10	0.10
Apr. 8	.39	.49	.52	.40	.36	.46	.57	.40	.56	.34	.29	.50	.36	.26	.27	.29	.22	.31	.42	.45
10	.72	.80	.75	.75	.85	.68	.68	.70	.73	.65	.63	.70	.69	.64	.64	.70	.75	.76	.74	.81
17	.09	.15	.39	.30	.10	.18	.07	.13	.08	.15	.02	.06	.02	0	0	0	0	0	0	0
18	.34	1.72	.56	.61	1.16	.26	.09	.27	.11	.30	.04	.12	.05	.04	.06	.12	.09	.10	.15	.02
29	.17	.24	.20	.22	.25	.10	.14	.23	.17	.18	.14	.20	.19	.14	.13	.15	.11	.10	.14	.11
Monthly Totals	1.71	3.40	2.42	2.28	2.72	1.68	1.55	1.73	1.65	1.62	1.12	1.58	1.31	1.08	1.10	1.26	1.17	1.27	1.45	1.39
May 1-2	.35	.50	.37	.41	.38	.35	.25	.42	.32	.40	.26	.36	.34	.35	.31	.36	.27	.25	.35	.29
5	.26	.60	.30	.35	.45	.29	.21	.35	.27	.34	.22	.31	.29	.13	.11	.13	.10	.09	.12	.10
10	.34	.13	.39	.25	.16	.35	.43	.23	.25	.21	.41	.12	.07	.63	.43	.15	.90	.74	.14	.60
15	1.52	1.33	1.24	1.10	1.17	1.20	1.34	1.50	1.30	1.61	1.27	1.30	1.49	1.58	1.74	1.84	1.88	2.27	1.90	1.88
16	.07	0	.15	.10	0	.14	.16	.14	.15	.15	.15	.12	.14	0	0	0	0	0	0	0
22	.74	.74	.71	.98	.80	.50	.69	.58	.48	.99	.71	.49	.65	.75	.56	.88	.78	.95	1.08	1.07
25	.03	.01	.13	.03	.01	.09	.13	.02	.09	.03	.13	.01	.02	0	0	0	0	0	0	0
Monthly Totals	3.31	3.31	3.29	3.22	2.97	2.92	3.21	3.24	2.86	3.73	3.15	2.71	3.00	3.44	3.15	3.36	3.93	4.30	3.59	3.94
June 1	1.70	1.80	1.86	1.59	1.74	1.48	.87	1.76	1.58	2.13	1.21	1.64	1.88	1.97	2.64	1.78	2.06	1.35	1.05	1.40
2	.49	.50	.53	.44	.48	.42	.25	.48	.45	.59	.34	.45	.52	.60	.80	.54	.62	.41	.32	.43
3	1.15	1.84	.81	1.62	1.78	.65	.38	1.80	.69	2.18	.54	1.68	1.92	.93	1.26	.84	.97	.64	.50	.67
3-4	2.42	2.10	2.91	2.61	2.57	2.50	2.41	2.75	2.46	3.06	2.17	2.60	2.55	2.22	2.30	2.73	2.00	2.20	2.14	1.68
5	.08	0	0	0	0	0	0	0	0	0	.16	0	.17	.05	.04	.24	.15	.40	.11	.44
8	.18	0	0	.05	trace	0	trace	.04	trace	0	.34	trace	.36	.10	.07	.50	.32	.85	.23	.94
22-23	.03	trace	.02	.02	.02	0	trace	trace	trace	0	trace	trace	trace	.02	.05	.08	.11	.20	.06	.10
23-24	.61	1.22	.48	.42	.73	.47	.63	.59	.47	.50	.59	.54	.58	.68	.52	.49	.66	.62	.52	.64
25-26	2.54	1.99	2.55	1.68	1.18	2.50	3.37	2.36	2.50	2.00	3.11	2.16	2.34	3.42	2.61	2.47	3.34	3.14	2.66	3.26
Monthly Totals	9.20	9.45	9.16	8.43	8.50	8.02	7.91	9.78	8.15	10.46	8.46	9.07	10.32	9.99	10.29	9.67	10.23	9.81	7.59	9.56

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1959																				
July 2	0.26	0.48	0.02	0.71	0.93	0	0	0.63	0	1.06	0	0.08	0.10	0	0	0.24	0	0	0.77	0
9	.09	0	0	0	0	0	0	.07	0	.05	0	.30	trace	0	.04	.05	.40	.12	.10	.65
15	.23	.15	0	.57	.18	0	0	.61	0	.54	0	.58	.51	.19	.19	.21	.20	.20	.23	.18
18	.37	.25	.05	.68	.29	.05	.05	.72	.03	.64	.05	.69	.60	.42	.43	.48	.45	.45	.52	.40
19	1.85	1.75	2.04	2.22	2.03	2.10	2.10	2.36	1.43	2.09	2.20	2.24	1.96	1.46	1.49	1.66	1.54	1.55	1.80	1.37
20	.98	.80	1.13	.66	.93	1.16	1.16	.70	.79	.62	1.21	.66	.58	1.08	1.11	1.23	1.14	1.15	1.34	1.01
21	3.36	2.97	3.51	3.29	3.49	3.62	3.63	3.49	2.48	3.09	3.79	3.29	2.89	3.23	3.34	3.77	3.41	3.45	4.03	3.04
Monthly Totals	7.14	6.45	6.75	8.13	7.85	6.93	6.94	8.58	4.73	8.09	7.25	7.84	6.64	6.38	6.60	7.64	7.14	6.92	8.79	6.65
Aug. 8	.46	.05	.18	.18	.20	.76	.54	.25	.28	.08	.38	.38	.41	.18	.54	.96	.42	.80	1.20	.90
24	.11	.57	.60	.11	.17	.12	.14	.16	.03	.04	trace	0	0	0	0	0	0	0	0	0
28	.05	0	0	0	0	0	0	0	0	0	0	0	0	.15	.11	.12	.11	.10	.15	.10
30	.07	0	0	0	0	0	0	0	0	0	0	0	0	.22	.16	.17	.17	.15	.23	.15
31	.73	.62	.68	.86	.95	.68	.83	.62	.70	.83	1.10	.90	.57	.83	.58	.64	.62	.55	.85	.57
Monthly Totals	1.42	1.24	1.46	1.15	1.32	1.56	1.51	1.03	1.01	0.95	1.48	1.28	0.98	1.38	1.39	1.89	1.32	1.60	2.43	1.72
Sept. 8	trace	trace	0	.03	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	.18	1.03	.06	.10	.25	.16	.12	.06	.20	.04	0	.19	.33	.09	0	.21	0	.05	.02	trace
24	.09	.05	.15	.21	.04	.10	.05	.17	.06	.26	.05	.14	.15	.05	.05	.06	.05	.05	.07	.06
29	.05	.25	.15	0	.19	.10	.05	0	.06	0	.05	0	0	0	0	0	0	0	0	0
30	1.24	2.57	1.56	1.75	1.95	1.03	.49	1.43	.59	2.16	.57	1.16	1.24	.82	.83	1.14	.83	.90	1.18	1.02
Monthly Totals	1.56	3.90	1.92	2.09	2.48	1.39	0.71	1.66	0.91	2.46	0.67	1.49	1.72	0.96	0.88	1.41	0.88	1.00	1.27	1.08
1959 WATER YEAR TOTALS	28.37	32.55	29.22	29.47	30.02	26.19	25.82	30.28	23.63	31.16	25.85	27.90	27.73	27.40	27.68	29.22	28.49	28.44	28.89	28.13
Oct. 3-4	4.18	3.53	3.99	4.15	4.25	4.02	4.41	3.95	4.80	4.35	4.71	4.00	3.88	4.29	4.10	4.28	3.85	4.29	4.37	4.70
13	.89	.53	.77	.78	.80	.76	.85	.86	.92	.80	.92	.90	.98	.93	.97	1.07	1.02	1.07	1.15	1.08
Monthly Totals	5.07	4.06	4.76	4.93	5.05	4.78	5.26	4.81	5.72	5.15	5.63	4.90	4.86	5.22	5.07	5.35	4.87	5.36	5.52	5.78
Nov. 1	.19	.25	.19	.27	.25	.13	.11	.18	.15	.20	.11	.17	.22	.20	.20	.25	.18	.13	.22	.17
3	.57	.87	.74	.65	.79	.54	.42	.68	.51	.51	.55	.58	.58	.58	.60	.62	.38	.36	.35	.27
14	.08	.05	0	0	.09	0	0	0	0	0	0	0	0	.19	.19	.17	.19	.20	.19	.20
15	.19	.10	.24	.26	.19	.20	.25	.29	.26	.22	.28	.28	.28	.14	.14	.12	.14	.14	.14	.14
Monthly Totals	1.03	1.27	1.17	1.18	1.32	0.87	0.78	1.15	0.92	0.93	0.94	1.03	1.08	1.11	1.13	1.16	0.89	0.83	0.90	0.78
Dec. 11	.17	.10	.13	.15	.16	.10	.12	.12	.13	.10	.18	.12	.16	.28	.25	.23	.22	.20	.19	.20
14-15	.64	.47	.71	.68	.72	.53	.62	.53	.68	.46	.96	.53	.73	.84	.75	.69	.68	.60	.56	.60
16	.61	.65	.74	.64	.65	.63	.64	.70	.73	.60	.68	.68	.62	.52	.54	.56	.50	.50	.48	.50
16-17	.39	.42	.41	.36	.42	.35	.36	.39	.40	.34	.37	.39	.35	.42	.43	.44	.40	.40	.39	.40
31	1.08	1.10	.98	1.10	1.15	1.05	1.12	1.08	1.17	1.09	1.08	1.04	1.06	1.06	1.07	1.10	1.02	.98	1.09	1.12
Monthly Totals	2.89	2.74	2.97	2.93	3.10	2.66	2.86	2.82	3.11	2.59	3.27	2.76	2.92	3.12	3.04	3.02	2.82	2.68	2.71	2.82

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number																		
		1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1960																				
Jan. 4-5	1.31	1.28	1.20	1.35	1.41	1.13	1.36	1.31	1.43	1.33	1.32	1.28	1.29	1.30	1.31	1.34	1.24	1.39	1.33	1.36
12	.41	.40	.45	.37	.43	.45	.40	.37	.54	.27	.49	.53	.40	.40	.38	.34	.34	.32	.39	.40
13	.86	.64	.90	.95	.77	.70	.91	.70	.89	.93	1.15	.62	.62	1.26	1.05	.82	.91	.98	.90	.82
14	.04	.11	.06	.05	.13	.05	.07	.04	.06	.05	.08	.03	.03	0	0	0	0	0	0	0
Monthly Totals	2.62	2.43	2.61	2.72	2.74	2.33	2.74	2.42	2.92	2.58	3.04	2.46	2.34	2.96	2.74	2.50	2.49	2.69	2.62	2.58
Feb. 2-3	.89	1.94	.70	.70	.90	.68	.80	.80	.85	.74	.90	.93	.62	.85	.90	.87	.78	.82	.78	.81
23	.26	.07	.36	.28	.30	.13	.30	.40	.25	.31	.32	.23	.25	.30	.30	.26	.29	.16	.30	.28
28-29	.04	.03	.03	.03	.04	.07	.04	.03	.04	.05	.04	.04	.04	.03	.08	.03	.04	.07	.04	.07
Monthly Totals	1.19	2.04	1.09	1.01	1.24	0.88	1.14	1.23	1.14	1.10	1.26	1.20	0.91	1.18	1.28	1.16	1.11	1.05	1.12	1.16
Mar. 13	trace	0	0	trace	trace	trace	trace	trace	.02	0	trace	.02	0	trace	0	trace	trace	0	trace	0
24	.37	.47	.46	.45	.47	.33	.38	.42	.33	.43	.34	.30	.32	.35	.32	.32	.35	.30	.33	.30
Monthly Totals	0.37	0.47	0.46	0.45	0.47	0.33	0.38	0.42	0.35	0.43	0.34	0.32	0.32	0.35	0.32	0.32	0.35	0.30	0.33	0.30
Apr. 13	.05	.06	.03	.05	.04	.10	.06	.04	.07	.05	.03	.03	.04	.02	trace	.04	.03	.10	.03	.04
24	.82	.34	2.44	.55	.37	1.50	1.30	.60	1.17	.65	1.61	.44	.50	.83	1.02	.62	.65	.35	.38	.35
25	.69	.50	1.30	.88	.55	.80	.70	.96	.63	1.04	.86	.71	.79	.71	.88	.53	.55	.30	.33	.30
26	.39	.22	.47	.48	.48	.42	.57	.47	.52	.37	.74	.27	.23	.50	.32	.26	.34	.30	.28	.34
27	.27	.22	.36	.68	.48	.32	.44	.66	.40	.52	.57	.38	.33	0	0	0	0	0	0	0
29	.56	.18	.29	.53	.39	.26	.35	.52	.33	.40	.46	.30	.25	1.37	.88	.72	.93	.82	.77	.94
Monthly Totals	2.78	1.52	4.89	3.17	2.31	3.40	3.42	3.25	3.12	3.03	4.27	2.13	2.14	3.43	3.10	2.17	2.50	1.87	1.79	1.97
May 4	.03	.05	0	trace	0	.10	.03	.02	.07	.02	.03	.02	trace	trace	0	trace	0	.10	0	0
17	.09	.05	.10	.04	.07	.06	.05	.03	.05	.03	.05	.02	.01	.28	.25	.11	.15	.15	.05	.16
18	.35	.62	.70	.91	.87	.42	.36	.65	.35	.77	.38	.41	.37	0	0	0	0	0	0	0
19	.33	.30	.42	.39	.37	.39	.36	.48	.46	.38	.30	.31	.32	.28	.25	.22	.27	.32	.27	.21
27	.49	1.40	.69	.96	1.29	.52	.42	.47	.33	.71	.47	.45	.52	.11	.14	.15	.13	.10	.15	.11
30	.32	.36	.30	.52	.33	.23	.19	.26	.14	.38	.21	.24	.28	.32	.41	.45	.39	.30	.43	.31
Monthly Totals	1.61	2.78	2.21	2.82	2.93	1.72	1.41	1.91	1.40	2.29	1.44	1.45	1.50	0.99	1.05	0.93	0.94	0.97	0.90	0.79
June 7	.11	.55	.08	.30	.42	trace	trace	.25	.03	.05	.07	.08	.02	.03	0	.02	0	0	0	0
11	.08	.10	0	0	trace	.05	0	0	0	.02	.35	0	.27	.34	.24	.11	.02	.02	.05	0
15	.14	.16	.18	.19	.14	.25	.12	.12	.07	.07	.12	.03	.05	.07	.04	.21	.17	.15	.22	.31
25	.25	.05	.12	.10	.08	.12	.23	.13	.23	.14	.29	.10	.37	.41	.38	.42	.30	.46	.47	.47
Monthly Totals	0.58	0.86	0.38	0.59	0.64	0.42	0.35	0.50	0.33	0.28	0.83	0.21	0.71	0.85	0.66	0.76	0.49	0.63	0.74	0.78

Table 12.--Summary of rainfall, in inches, for Mukewater Creek study area, October 1953 to September 1960--Continued

Date of storm	Storm WMR	Gage Number 1-R	2-S	3-S	4-S	5-R	6-S	7-S	8-S	9-R	10-S	11-S	12-S	13-S	14-S	15-S	16-S	17-R	18-S	19-S
1960																				
July 15	0.01	0	0	0.05	0	0	0	0.02	0	0.05	0	0.01	0.02	0	0	0	0	0	0	0
16	.57	0	0	.83	0	0	0	.28	0	.88	0	.20	.44	1.06	.64	1.53	1.52	1.33	1.22	1.20
18	.11	.04	.07	0	.28	.04	.13	0	.10	0	.16	0	0	.15	.09	.22	.22	.19	.17	.17
19	.32	.13	.41	.28	.92	.24	.82	.09	.60	.30	.98	.07	.15	.17	.10	.24	.24	.21	.19	.19
20	.28	.19	.30	.12	.18	.19	.38	.31	.33	.16	.23	.14	.14	.50	.25	.64	.30	.27	.32	.24
24	.15	.67	0	.18	.64	0	0	.45	0	.23	0	.20	.20	0	0	0	0	0	0	0
26	.20	.28	.37	.23	.26	.23	.47	.57	.41	.29	.28	.26	.25	0	0	0	0	0	0	0
Monthly Totals	1.64	1.31	1.15	1.69	2.28	0.70	1.80	1.72	1.44	1.91	1.65	0.88	1.20	1.88	1.08	2.63	2.28	2.00	1.90	1.80
Aug. 9	1.21	1.15	.37	.95	.91	.27	.27	.91	.38	1.05	.52	1.62	1.70	1.72	1.65	1.68	2.20	2.12	1.54	2.26
10	.71	.73	.83	.30	.58	.60	.60	.29	.85	.33	1.15	.51	.54	.80	.77	.78	1.03	.99	.72	1.06
11	.08	.06	0	.24	.05	0	0	.23	0	.26	0	.40	.42	0	0	0	0	0	0	0
15	.31	.28	.36	.16	.22	.26	.27	.15	.37	.18	.50	.27	.29	.33	.33	.34	.42	.41	.29	.44
20	.08	0	.05	0	0	.03	.01	0	.04	0	.01	0	0	0	0	trace	.24	.40	.29	.57
21	.14	.47	.19	.30	.43	.12	.03	.29	.15	.42	.03	.17	0	0	0	0	0	0	0	0
30	.15	0	.05	0	0	.02	.15	.01	.27	0	.23	.16	.35	.07	.16	.54	.03	.20	.53	.23
Monthly Totals	2.69	2.69	1.85	1.95	2.19	1.30	1.33	1.88	2.06	2.24	2.44	3.13	3.30	2.92	2.91	3.34	3.92	4.12	3.37	4.56
Sept. 23	1.08	1.45	1.32	1.18	1.31	1.68	1.14	1.35	1.33	1.11	1.20	1.38	1.35	.77	.64	.60	.71	.60	.72	.55
24	.54	.21	.54	.30	.19	.68	.46	.34	.54	.28	.48	.35	.34	.91	.76	.71	.84	.71	.86	.65
25-26	.13	.22	.11	.11	.20	.14	.10	.13	.11	.11	.10	.13	.13	.14	.12	.11	.12	.11	.13	.10
Monthly Totals	1.75	1.88	1.97	1.59	1.70	2.50	1.70	1.82	1.98	1.50	1.78	1.86	1.82	1.82	1.52	1.42	1.67	1.42	1.71	1.30
1960 WATER YEAR TOTALS	24.21	24.05	25.59	25.03	25.97	21.97	23.26	23.93	24.59	24.03	26.98	22.33	23.10	26.14	24.20	24.76	24.61	24.23	23.61	24.62