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May 28, 1952

To the Graduate Council:

I am submitting herewith a thesis written by Bernard H. Zellner entitled "A Study of the Hydrology of the Cane Creek Watershed." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

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A STUDY OF THE HYDROLOGY OF THE CANE CREEK WATERSHED

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by
Bernard High Zellner

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CHAPTER I

THE PROBLEM

Hydrology is usually defined as the study of the occurrence and distribution of water over and within the earth's surface and the accompanying basic natural laws and phenomena (2). It treats specifically of the occurrence of water on the earth, the description of the earth with respect to water, the physical effect of water on the earth, and the relation of water to life on the earth (6).

The hydrologic cycle is a descriptive term applied to the general circulation of water from the seas to the atmosphere, to the ground and back to the seas again. The cycle may be considered to begin at any point, but normally the oceans are considered as the beginning points. Water from the oceans is evaporated into the atmosphere. This vapor is condensed by various processes and falls to the earth as precipitation. Some of this precipitation falls directly into the oceans, and some falls on the land surfaces. A portion of that falling on the land is retained temporarily in the soil, in surface depressions, and on vegetation and other objects until it is returned to the atmosphere by evaporation and transpiration. The remainder of the water, moving by surface and underground channels to rivers, lakes, and eventually to the oceans, is also subject to evaporation and transpiration throughout its travels (6).

The foregoing description of the hydrologic cycle is greatly oversimplified. Actually, all phases of the cycle are occurring

simultaneously. On a world-wide basis the volumes of moisture involved in each phase of the cycle are relatively constant, but when viewed in terms of a limited area, such as a small river basin, the quantities in any part of the cycle vary through wide limits. These variations are the primary subjects of study in hydrology. For example, a temporary unbalance of the cycle in which great volumes of water are concentrated in the streams results in a flood. Conversely, small or negligible amounts of water in the precipitation phase of the cycle lead to drought (6).

The problem in this particular case is to firmly establish the hydrologic characteristics of the Cane Creek watershed so that any changes in the hydrologic relationships wrought by the application of proposed conservation practices may be detected.

In making such a study, an analysis must be made of past hydrologic records of the watershed, or for some phases of such a study, the records from adjacent areas may be used. These hydrologic records should include records of precipitation, stream flow, and temperature.

By the use of the above-mentioned records the hydrologic characteristics of a particular area, such as the Cane Creek watershed, may be firmly established. In the establishment of the hydrologic characteristics of an area, a study is normally made of monthly and annual precipitation, monthly and annual stream flow, rainfall-runoff relationships, storm relationships, and other pertinent relationships that would aid in defining the hydrology of the area.

CHAPTER II

THE CANE CREEK WATERSHED

Location

Cane Creek drains the second largest tributary watershed in the Beech River Basin. This watershed, containing 25.5 square miles, heads in the vicinity of Reagan, Henderson County, Tennessee, and stretches northward approximately 10 miles, to the vicinity of Chesterfield, Tennessee. Cane Creek enters Beech River from the south approximately two miles southeast of Chesterfield. From the point where Cane Creek enters Beech River, it is approximately 12 miles to the point of confluence between Beech River and Kentucky Reservoir. This point of confluence is located approximately 113.3 miles above Kentucky Dam (4). Plate 1 shows the Cane Creek watershed in relation to the Beech River watershed. Plate 2 shows the Cane Creek watershed.

Topography

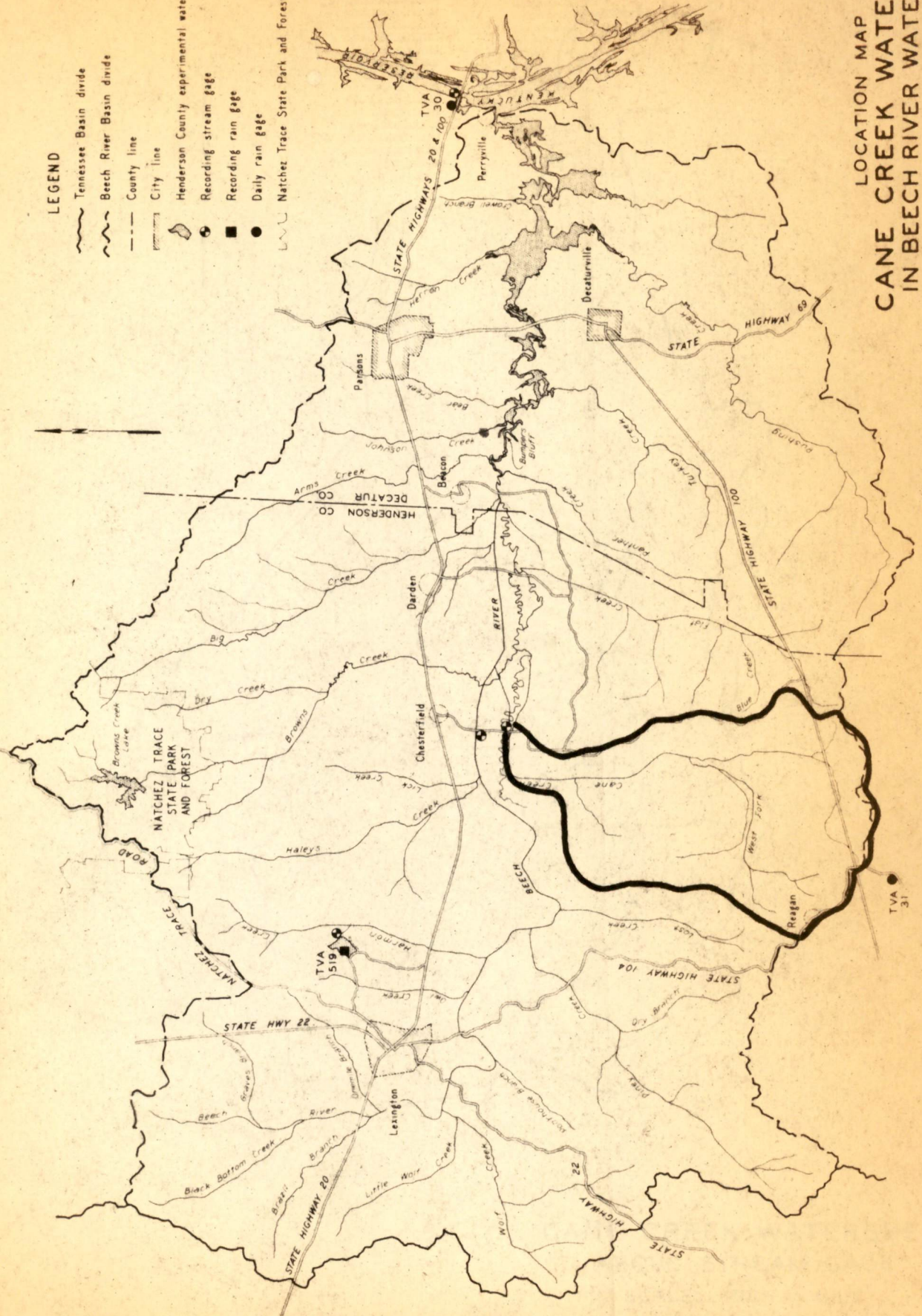
The Cane Creek watershed is an area of relatively low relief varying in elevation from approximately 650 feet above sea level in the upper headwater area to approximately 368 feet above sea level at the point where Cane Creek enters Beech River. The southern and western headwater area has a highly dissected landscape with long, very narrow, and winding ridge crests with irregular, short, and moderately steep slopes. The eastern headwater area is more regular in appearance with an undulating to rolling topography. The central portion of the Cane Creek watershed, the area through which Cane Creek flows, has a weakly

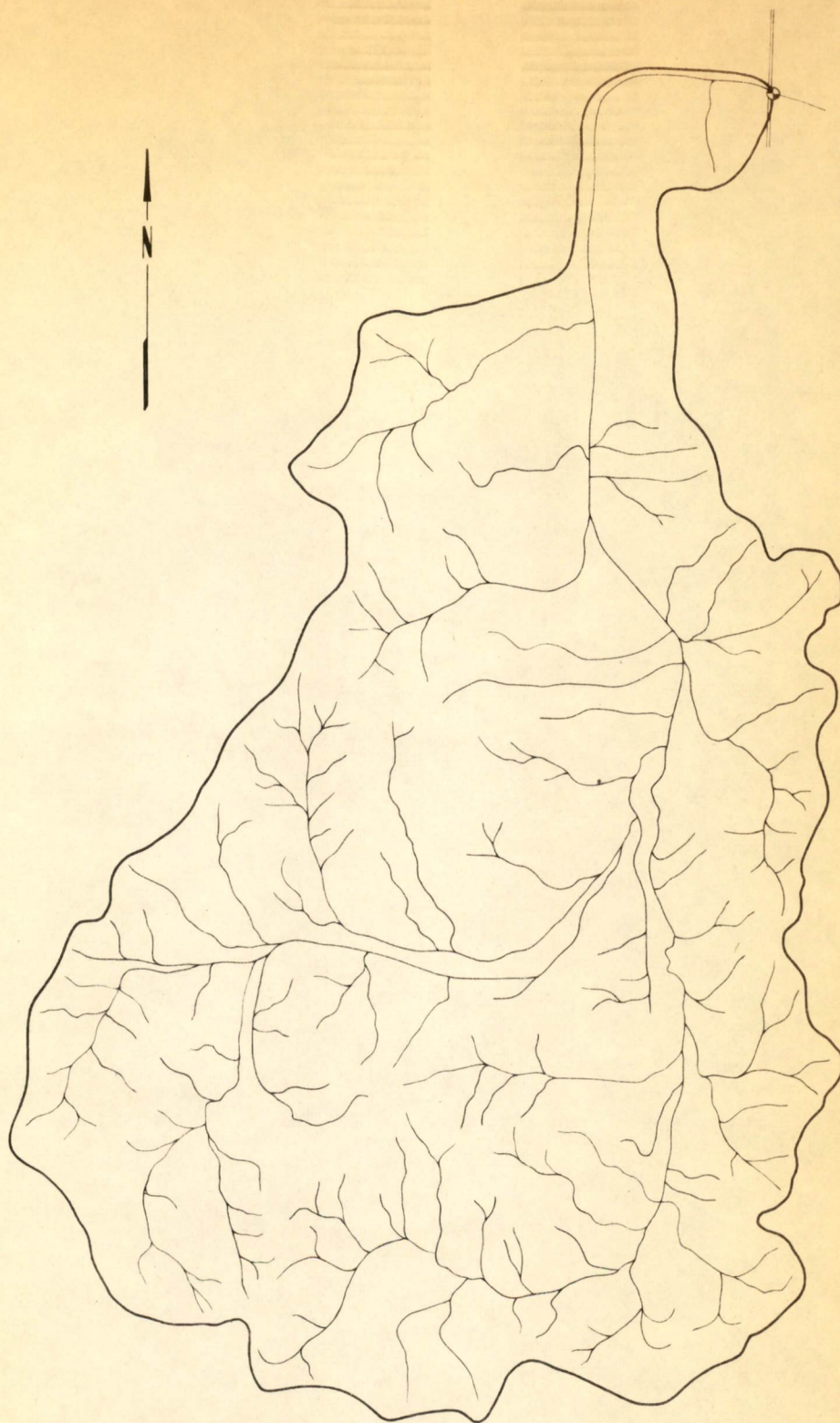
LOCATION MAP CANE CREEK WATERSHED IN BEECH RIVER WATERSHED

SCALE 0 1 2 3 4 5 MILES

LEGEND

- Tennessee Basin divide
- Beech River Basin divide
- County line
- City line
- Henderson County experimental watershed
- Recording stream gage
- Recording rain gage
- Daily rain gage
- Natchez Trace State Park and Forest boundary





CANE CREEK WATERSHED
ABOVE STREAM GAGE
SCALE: 1 INCH = 1 MILE

dissected, undulated, and gently rolling topography. In the lower reaches, Cane Creek flows through a low, broad bottom, that is subject to flooding at frequent intervals.

Stream Pattern

The Cane Creek drainage forms a dendritic pattern. From the point where East Fork Cane Creek and West Fork Cane Creek come together to form Cane Creek, Cane Creek flows northward for approximately four miles, then flows eastward two miles to its confluence with Beech River draining approximately 25.5 square miles.

The mean slope of Cane Creek is rather steep, being 7.5 feet per mile. The upper reaches, however, are much steeper than the lower reaches. The slope of the first mile in the headwater area is approximately 15 feet per mile, and the slope of the first five miles is about 11 feet per mile. The slope of final mile before entering Beech River is approximately 4.5 feet per mile. The total length of Cane Creek is 9.65 miles and the total difference in elevation for this reach is approximately 73 feet (4).

Drainage Canal

About 1916, a canal was constructed along the general course of Cane Creek. The exact original dimensions of this canal are unknown, but during the last twelve years the width at the Chesterfield road crossing has varied from 28 to 30 feet. The maximum depth in 1940 was nine feet. Since 1940, however, there has been a rapid deterioration of the Cane Creek drainage canal channel, until, in 1951, its discharge

capacity at bankfull stage, is only 27 percent of its 1940 capacity at bankfull stage (4).

Land Use and Capability

The Cane Creek watershed is an area of small farms. When viewed from the air, its surface shows a patchwork of forest, pasture, and cultivated land. Approximately 32 percent of the watershed is forested. The most extensive non-forested area is the Freeland, Hymon, Beechy soil association lying adjacent to Cane Creek. The most extensive forested areas, in general, lie in the headwater areas of the Cane Creek tributaries. The dominant soil associations in these areas are the Safford-Dulac-Silerton Association, the Dulac-Silerton-Safford Association, and the Ruston-Lexington Association. These soils when cleared are highly erosive. Since a substantial portion of these associations have been cleared and are badly eroded, they create a serious problem with respect to filling of stream channels and control of surface runoff (7).

Table I gives the area occupied by each soil association and the percentage of forested land by soil associations.

The following paragraphs describe, briefly, the soil associations of the Cane Creek watershed.

The Beechy-Hymon soil association consists of the first bottoms and associated colluvial lands along the Beech River and its major tributaries. Beechy and Hymon soils also occur in the first bottoms of the other soil associations described below. This association, comprising 3.5 percent of the Cane Creek watershed, floods at frequent

TABLE I

SOIL ASSOCIATIONS - CANE CREEK WATERSHED

	Sq. Miles	% of Total	% Forested
Beechy-Hymon	0.90	3.54	26
Ruston-Lexington	1.00	3.93	65
Safford-Dulac-Silerton	9.97	39.16	52
Dulac-Silerton-Safford	4.79	18.81	30
Freeland-Hymon-Beechy	<u>8.80</u>	<u>34.56</u>	10
	25.46	100.00	

intervals and cannot be safely used for row crops at present because of this hazard. Pastures produced on this association are generally of poor quality (7).

The Ruston-Lexington soil association consists of a highly dissected landscape. The ridge tops, except for the main divides, are very narrow and winding, with the ridge slopes irregular, short, and moderately steep. Lexington or Providence soils are on the ridge crests, Ruston soils on the ridge slope, Briensburg soils on the colluvial footslopes, and Beechy or Hymon soils on the first bottoms. Approximately 64 percent of the area, the alluvial and forested soils, is not susceptible to accelerated erosion. About 70 percent of the cleared upland, however, is severely eroded. A large part of this severely eroded acreage consists of Ruston soils which are not generally considered suitable for either crops or pasture. These severely eroded soils, however, are well adapted to pine production with erosion being stabilized within 5 to 8 years on most sites. The Lexington and Providence are, in general, only moderately eroded, and, with good management, are considered suitable for crops and pasture (7).

The Safford-Dulac-Silerton soil association is highly dissected with narrow, winding ridge crests, and short, irregular and moderately steep ridge slopes. Dulac and Silerton soils are on the ridge crests, Safford soils on the ridge slopes, Briensburg soils on the colluvial footslopes, and Hymon and Beechy soils in the first bottoms. In their present condition only a small part of the cleared upland soils are suitable for crops, but most farms have an appreciable acreage of

Briensburg, Hymon, and Beechy soils that are suitable for the production of row crops. A considerable part of the cleared upland has been severely eroded, but not severely gullied, and can be reclaimed easily for pasture. The relatively large acreage of forage-crop adapted bottom land plus upland suitable for pasture would indicate that this area has a considerable potential for livestock production (7).

The Dulac-Silerton-Safford soil association is an area of undulating to rolling terrain. Dulac soils are on the least sloping uplands and Safford soils are on the small area of hilly and steep uplands, with the Silerton soils on the ridge slopes. The soils of this association are, for the most part, naturally infertile and limited in use suitability (7).

The Freeland-Hymon-Beechy soil association, consisting of terraces and bottom lands, is weakly dissected with an undulating to gently rolling topography. The soils of this area are well suited to crop production. The use suitability of the Freeland soils, the most extensive soils in this area, is slightly restricted and the productivity is moderately low, because of restricted internal drainage and root penetration. The productivity of the Hymon and Briensburg soils is comparatively high, but crop adaptation on these soils is slightly limited by imperfect drainage and susceptibility to overflow. The poorly drained Beechy soils are poorly suited to crop production but are good pasture soils (7).

CRANES CREST

Climate

The Cane Creek watershed does not lie directly within any of the principal storm tracks that cross the country but this area comes under the influence of the storm centers passing along two of these tracks, namely, the southern track through northern Texas to Louisiana, along the Gulf coast, thence up the Atlantic coast, and the track from Oklahoma northeastward to the Great Lakes, thence to the coast of Maine. Therefore, weather changes in this area are moderately frequent when compared with the stable conditions of the far southwest, but weather changes appear to be rather stable when compared with the very frequent changes of the Lake region (10).

Table II is a summary of the climatic data for the area surrounding the Cane Creek watershed.

Normally, in the Cane Creek watershed, the summers are hot, but a sufficient supply of moisture for crop production is usually available. The winters are usually cool and moderately wet (4).

The mean annual temperature is 60 degrees; however, the difference between the maximum temperature of 110 degrees and the minimum temperature of -21 degrees is 131 degrees. Zero temperatures occur, on an average, not oftener than once a year. Occasionally, however, the temperature falls considerably below zero, as shown by the record low temperatures. These low temperatures rarely endure more than a few days. During the summer, temperatures exceeding 110 degrees are occasionally reached. July and August normally have the highest temperatures with maximum of approximately 110 degrees (10).

TABLE II

CLIMATIC DATA - CANE CREEK WATERSHED
1897-1951

Month	Precipitation		Temperatures				
	Mean Monthly inches	Rainy Days ave.no.	Average	Average Maximum	Average Minimum	Highest	Lowest
Jan.	5.52	10	41	50	31	78	-17
Feb.	4.31	10	42	53	31	82	-21
March	4.80	10	51	62	41	90	5
April	4.39	10	60	72	48	93	23
May	3.91	10	68	80	56	101	31
June	4.04	10	76	88	63	104	41
July	3.73	10	80	92	67	109	47
Aug.	3.52	9	79	91	66	110	48
Sept.	3.06	7	73	86	61	108	32
Oct.	2.69	6	61	75	48	96	21
Nov.	4.13	8	50	62	38	86	2
Dec.	4.99	10	42	51	32	77	-20
Annual	49.09	110	60	72	48	110	-21

The mean annual precipitation over the watershed is approximately 49 inches with about 21 inches falling in the May-October period and 28 inches in the November-April period. The wettest months are January, December, and March and the driest months are September and October. On an average, there are about 110 days with measurable rainfall each year, with clear skies prevailing on about 140 days. It is partly cloudy on about 105 days, and cloudy on approximately 120 days. Snowfall averages about two percent of the total precipitation (10).

The growing season for the Cane Creek watershed area is approximately 200 days. The average date for the last killing frost is about April 7, and the first killing frost in the autumn usually occurs about October 20. Killing frosts have occurred as late in the spring as early May and as early in the autumn as the latter part of September (10).

CHAPTER III

HYDROLOGIC INVESTIGATIONS, 1940-1951

During the winter of 1939-1940, nearly five years before Kentucky Dam was closed, the TVA began collecting hydrologic data on Beech River and other large tributaries of Kentucky Reservoir, primarily to determine the effect, if any, of the reservoir on flood heights on these streams and on ground-water levels in the farm lands bordering the reservoir. Stream gaging stations were installed just above the upper limit of reservoir influence. Flood crest markers were placed along the streams on reaches extending upstream and downstream from normal reservoir level. Rain gages were installed to supplement the then existing precipitation network. Shallow ground-water wells were installed in bottom lands where a raised water table might affect farming operations (4).

During this period, a recording stream gage was established on Cane Creek near the bridge on the road south of Chesterfield. This location is shown on Plate 1. Two flood crest markers were also established to provide flood crest profiles for the lower four miles of Cane Creek (4).

Ground-water wells were installed in the Beech River bottoms and in the lower reaches of Cane Creek, Flat Creek and Big Creek. However, ground-water observations were discontinued in 1946 when it was determined that the rise in the Tennessee River caused by Kentucky Dam had not affected the ground levels above Big Creek (4).

No rainfall stations were established in the Cane Creek watershed. Reagan, TVA station number 31, is within one mile of the edge of the headwater area, and Oak Grove, TVA station number 519, is approximately five miles north of the northern edge of the watershed.

CHAPTER IV

PRECIPITATION

Precipitation Stations

There are no precipitation stations located in the Cane Creek watershed. The radio station at Lexington and the recording station at Reagan were used in calculating an average rainfall for 1940, while the Oak Grove recording station and the Reagan recording station were used in calculating the weighted averages for the years 1941-1951 (1). These stations, their distances and directions from the watershed boundary, and their weight factors are shown in Table III.

The Mean and Extreme Rainfall

The mean annual rainfall for the Cane Creek watershed is approximately 49 inches using data from the thirty years of record at Reagan, while the weighted mean for the period of stream flow record using data from the Oak Grove and Reagan stations is approximately 53 inches.

The driest and wettest years since 1891 occurred during the period of stream flow record on Cane Creek with 1941 the driest year and 1950 the wettest year (4). During 1941, the driest year, Reagan registered 26.82 inches and Oak Grove 28.72 inches. The weighted average for the watershed was 27.01 inches. The year 1950 was the wettest of a series of wet years beginning in 1944 and it is probable that its rainfall exceeded all others in the past 60 years of record for this area (9). Oak Grove reported 68.25 inches and Reagan 63.79 inches with the weighted average being 64.25 inches. Precipitation

TABLE III

PRECIPITATION STATIONS
IN THE VICINITY OF CANE CREEK WATERSHED

Year	Station No.	Name	Distance and Direction from Boundary	Weight Factor (Percent)
1940	460	Lexington Radio	Three miles northwest	26
1940	31	Reagan	One mile south	74
1941-51	519	Oak Grove	Five miles northwest	10
1941-51	31	Reagan	One mile south	90

averaging 60 inches or more was registered in 1944, 1945, 1948, 1949, 1950, and 1951.

The mean monthly precipitation for the Cane Creek watershed as shown by Table IV ranges from 5.52 inches in January to 2.69 inches in October.

The wettest month in the 30 years of record at Reagan, the nearest station to the Cane Creek watershed, was January 1937, when 15.97 inches were recorded (10). The wettest month during the period of stream flow record was January 1950 when 14.65 inches fell at this station (5). The driest month on record at Reagan was October 1908 when only a trace of precipitation was recorded (10). The driest month during the period of record was May 1951 when 0.07 of an inch was recorded (5).

Storm Rainfall

The Cane Creek watershed is subject to storms resulting from cyclonic disturbances moving across the Tennessee Valley during the winter and spring, and to convectional type storms occurring during the summer. The winter storms, as a general rule, produce the highest floods, but the summer storms cause the greatest damage because of their effect on crops (4).

The largest storms, according to local residents, within the past fifty years in the Cane Creek area occurred on March 16-17, 1919. This downpour came in conjunction with a disturbance that moved slowly across the Mississippi Valley, causing tornadoes in Louisiana and Mississippi and causing heavy rains in several states. In Tennessee

TABLE IV

MONTHLY PRECIPITATION - MEANS AND EXTREMES
1897 - 1951

Month	Mean Precipitation Cane Creek Watershed inches	Extremes at Reagan			
		Maximum inches	Year	Minimum inches	Year
Jan.	5.52	15.97	1937	1.10	1909
Feb.	4.31	10.83	1939	0.97	1941
Mar.	4.80	7.92	1949	0.64	1910
Apr.	4.39	11.62	1911	1.64	1902
May	3.91	8.57	1904	0.07	1951
June	4.04	10.34	1900	0.63	1941
July	3.73	8.64	1937	0.97	1947
Aug.	3.52	8.00	1911	0.34	1948
Sept.	3.06	6.57	1906	0.44	1941
Oct.	2.69	7.82	1905	0.00	1908
Nov.	4.13	12.26	1906	1.04	1901
Dec.	<u>4.99</u>	12.69	1911	0.79	1935
	49.09				

the heaviest rain fell along a line extending from Memphis northeastward to Henderson in Chester County and Perryville in Decatur County. Memphis recorded 9.72 inches for the storm, Arlington in Shelby County had 10.05 inches, Henderson had 10.58 inches, and Perryville had 10.08 inches. The mean storm rainfall for the Cane Creek watershed was approximately 9.0 inches (4). The storm lasted approximately 30 hours with a large percentage of the rain falling during the day of March 16.

The storm producing the greatest flood during the twelve-year period of stream flow record occurred in early January 1946. Light to moderate rain fell in the area during the first six days in January, totalling 0.8 inch in the three days before the storm. The heavy rain began at 7 p.m. on January 6 and fell almost continuously until 11 p.m. on January 8, a duration of 52 hours. Oak Grove recorded 6.83 inches during the period, and Reagan registered 7.24 inches. This is an average of 7.2 inches over the Cane Creek watershed (4).

The second largest flood during the period of stream flow record occurred in February 1948. The storm rainfall that caused this flood, averaging 7.2 inches over the Cane Creek watershed, was approximately equal to the storm of January 1946, but the time distribution of the rainfall caused a reduction in the peak discharge. There had been no rain during the previous three days prior to the storm, but there had been approximately an inch during the two weeks preceding the storm. The duration of the storm was approximately 54 hours, practically the same as the January 1946 storm. The total storm rainfall recorded at Oak Grove and Reagan was 5.89 and 7.35 inches, respectively (4).

The third largest flood between 1940 and 1952 was produced by the storm of November 18-19, 1948. Less than one-half inch fell during the three days prior to the storm, but more than four inches had fallen during the month. Therefore, the ground was very wet. This storm was intense with a duration of only 16 hours. The average storm rainfall over the Cane Creek watershed was 5.6 inches, with Oak Grove recording 3.5 inches and Reagan registering 5.73 inches.

Table V lists data on these and other typical storms occurring during the 12 years of stream flow record on Cane Creek (4).

A study of Table VI indicates that the storm rainfall required to fill the Cane Creek channel to bankfull stage of 7.5 feet is less at present than it was during the early years of stream flow record. This condition is the result of deterioration of the channel resulting in less capacity.

Monthly and Annual Precipitation

The weighted mean precipitation for each month and year, the average weighted mean by months and years, and the average yearly precipitation for the period of record are shown by Table VII. Inspection of this table shows that the first two years of the period of record were very dry, with the next two years (1942-1943) moderately dry and the final eight years (1944-1951) abnormally wet. The information in this table was used in calculating a cumulative precipitation table. This table was then used as one of the variables in the construction of mass and double mass curves.

TABLE V

TYPICAL STORMS AND DISCHARGE DATA
CANE CREEK WATERSHED

Date	Duration hours	Rain inches	Crest feet	Initial Discharge cfs	Peak Discharge cfs
Jan. 6, 1946	52	7.2	9.13	13	5330
Feb. 13, 1948	54	7.2	8.98	16	3850
Mar. 31, 1948	9	2.2	8.43	19	784
Apr. 8, 1942	24	4.3	8.23	3	691
May 6, 1950	15	1.8	8.65	16	407
June 6, 1945	9	1.5	8.08	6	330
July 5, 1946	6	2.4	8.28	5	492
Aug. 31, 1950	21	2.3	8.50	11	333
Sept. 2, 1950	17	1.7	8.76	24	480
Oct. 5, 1944	12	2.8	8.10	5	415
Nov. 19, 1948	16	5.6	9.25	11	1240
Dec. 28, 1942	18	3.5	8.40	5	1000

TABLE VI

STORM RAINFALL TO PRODUCE BANKFULL STAGE OF 7.5 FEET
CANE CREEK NEAR CHESTERFIELD GAGING STATION

Date of Storm	Av. Storm Rainfall	Initial Discharge	Peak Stage (ft)	Peak Discharge (ft)
Nov. 11, 1940	1.9	2	7.20	457
Apr. 18, 1940	1.8	8	7.57	524
Dec. 31, 1941	1.6	4	7.35	327
Mar. 16, 1943	0.6	13	7.52	184
Mar. 6, 1944	0.6	16	7.51	183
Nov. 19, 1944	1.2	13	7.52	184
Jan. 18, 1945	0.7	19	7.44	173
Dec. 4, 1945	1.0	11	7.44	147
Nov. 16, 1946	0.8	10	7.54	160
Nov. 8, 1950	1.2	11	7.30	119
Jan. 10, 1951	0.5	17	7.68	152
Apr. 12, 1951	0.4	15	7.70	154

TABLE VII

MONTHLY PRECIPITATION DATA IN INCHES - CANE CREEK WATERSHED

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	2.05	5.74	5.48	3.58	1.88	2.59	3.40	1.95	0.43	1.35	4.53	3.79	36.77
1941	2.16	0.98	1.64	2.18	1.25	0.67	3.93	3.37	0.42	3.85	3.65	2.91	27.01
1942	3.04	3.58	5.26	5.28	1.59	2.26	4.10	3.17	4.00	3.74	2.28	7.21	45.51
1943	2.13	1.18	6.82	3.28	4.22	2.46	3.47	5.19	6.04	0.72	3.68	3.74	42.93
1944	2.60	9.59	6.54	7.34	2.14	3.75	3.06	5.86	3.79	3.03	4.16	8.01	59.87
1945	4.50	7.36	4.95	6.33	5.87	5.91	1.84	3.29	5.62	3.19	8.20	5.36	62.42
1946	10.97	5.66	6.74	2.56	4.49	1.95	5.55	3.73	5.86	2.18	4.58	3.42	57.69
1947	8.65	0.99	3.84	5.62	7.16	2.54	1.03	4.47	3.18	4.30	5.86	2.46	50.10
1948	5.42	10.58	7.82	3.59	1.90	2.13	6.82	0.39	5.40	1.72	11.74	6.55	64.06
1949	9.43	3.11	7.76	2.98	8.38	5.57	4.04	6.11	2.02	5.24	1.29	6.26	62.19
1950	14.73	6.16	6.84	1.78	5.32	4.45	4.54	5.42	4.58	1.37	6.46	2.59	64.24
1951	9.91	5.56	4.76	4.48	0.08	6.60	4.23	2.18	2.83	1.98	8.59	9.47	60.67
Total	75.59	60.49	68.45	49.00	44.28	40.88	46.01	45.13	44.17	32.67	65.02	61.77	633.46
Ave.	6.30	5.04	5.70	4.08	3.69	3.41	3.83	3.76	3.68	2.72	5.42	5.15	52.78

CHAPTER V

STREAM FLOW

Stream Gaging Stations

The discharge of the Cane Creek watershed is being measured at only one station. This gaging station is located south of Chesterfield a few feet from the bridge crossing Cane Creek. This weekly recording gage, shown in Figure 1, was established January 18, 1940. It is set over a 24-inch stilling well (4).

During floods the discharges of Cane Creek and Beech River overflow their banks and spread out over the bottoms to a width of 7000 feet. The streams join in the vicinity of the Beech River slough shown on Plate 1. A considerable portion of the high flow is over the Chesterfield road and through numerous overflow bridges and culverts (4).

Deterioration of the Channel

There has been a progressive deterioration of the Cane Creek channel between 1940 and 1951. This deterioration has reduced the channel at bankfull stage to only 27 percent of its capacity in 1940. Figures 2 through 9 show the condition of the channel at various times during the period.

The lower two miles of the Cane Creek channel was still in good condition in 1939 and early 1940 after the work that was done in 1937. The period beginning in the summer of 1940 and extending through 1941 was the driest period in more than 50 years of record. Between June 1 and October 31, 1941, there was no flow in Cane Creek and during this



Figure 1. Cane Creek Gaging Station

This view, taken January 22, 1951, shows the stream gage on Cane Creek along the road leading south from Chesterfield, Tennessee.



Looking upstream



Looking downstream

Figure 2. Cane Creek Drainage Canal in December 1939

The Cane Creek canal, shown here in the vicinity of the Chesterfield Road, was in very good condition when these pictures were taken on December 19, 1939.



Looking upstream



Looking downstream

Figure 3. Vegetation in Cane Creek Canal in June 1942

During the summers of 1941 and 1942 there was no flow in Cane Creek for long periods, and vegetation began to grow up in the channel. These views are looking up and downstream from the Chesterfield Road bridge. Taken on June 24, 1942.



Figure 4. Brush and Debris Above Cane Creek Bridge

By April 18, 1946, when this picture was taken, brush had nearly filled the channel of Cane Creek at the Chesterfield Road bridge.



Figure 5. Cane Creek Bridge Blocked by Drift

The waterway under the bridge was almost completely blocked with drift when this picture was taken on April 18, 1946.



Figure 6. Trees and Drift Hindered Flow in March 1949

By 1949 the Cane Creek canal was badly choked with vegetation, sediment, and drift. This view looking downstream from Chesterfield Road bridge was taken on March 10, 1949, with a flow of about 100 cubic feet per second.



Figure 7. After Channel Clearing in April 1950

In April 1950, farmers along Cane Creek near Chesterfield cleared brush and trees and dynamited drifts and sediment deposits from a 1200-foot reach of the creek. This view taken on April 17, 1950, is looking downstream at the Chesterfield Road bridge.



Looking upstream



Looking downstream

Figure 8. Dynamiting Partially Cleared Cane Creek in 1950

These two views from Chesterfield Road bridge show the reach extending 600 feet upstream and 600 feet downstream from the bridge that was cleaned out in April 1950. Taken on April 17, 1950, after most of the work had been completed.



Looking upstream



Looking downstream

Figure 9. Cane Creek Ditch in March 1951

These views, taken on March 16, 1951, a year after the channel of Cane Creek was cleared out, show that vegetation was again taking hold on the banks.

time grass and weeds grew in the bed of the stream. Figure 3 shows the vegetal cover in 1942. The interference to flow caused by this vegetation and the accumulation of sediment in the stream resulted in a very sharp reduction in channel capacity. Discharge measurements made in 1941-1942 showed that in those years a flow of 360 cubic feet per second filled the channel to bankfull stage as compared to 510 cubic feet per second in 1940. The growth of vegetation and the accumulation of sediment continued through 1943 and 1944 but with a reduced rate. The channel capacity in 1943-1944 was 320 cubic feet per second.

In 1944 or 1945, Mrs. Ada Rogers, whose property is on the old Cane Creek drainage canal about one mile downstream from the gaging station, sold the timber on her land to outside interests (4). In cutting the timber, tree tops and logs were allowed to fall into the channel. They were never removed. This condition contributed greatly to the drastic reduction in channel capacity that occurred during this period. Between the spring of 1944 and the spring of 1945, the capacity of the Cane Creek channel at bankfull stage dropped from 320 cubic feet per second to 160 cubic feet per second. From 1945 to 1951, as shown by Figures 4 to 6, the channel has continued to deteriorate but at a greatly reduced rate. The 1951 rating table shows a channel capacity at bankfull stage of 140 cubic feet per second, 27 percent of the 1940 discharge at this stage. Table VIII shows channel capacities for various periods of stream flow record.

Minor attempts have been made to improve the channel by clearing the channel of vegetation and sediment at certain points. In April

TABLE VIII

CHANNEL CAPACITIES FOR CANE CREEK
NEAR CHESTERFIELD 1940-1951

Period	1940	1941-42	1943-44	1945-46	1947-50
Capacity - cfs	510	370	320	160	140
Percent of 1940 capacity	100	72	63	31	27

1950, farmers spent \$350 in clearing brush and trees from the canal and its banks for a distance of 600 feet above and below the gaging station. Drifts and heavy sediment deposits were dynamited (4). Figures 7 and 8 show Cane Creek after this work was completed. Apparently nothing was done on the Rogers property and the work near the gage had little effect. By summer the vegetation was again growing, and by the spring of 1951, conditions in the reach were nearly as bad as before. This condition is shown by Figure 9.

Monthly and Annual Discharges

Tables IX, X, and XI present total runoff, surface runoff and ground-water runoff, in inches, by months and years.

The wettest year during the period of stream flow record was 1950 and the driest year was 1941. An annual cycle is evident, especially in the ground-water runoff, with the maximum values occurring in the winter and the minimum values occurring in the fall. The total annual runoff varied from 1.15 inches in 1941 to 30.53 inches in 1951. The maximum monthly total runoff was 10.22 inches in January 1951 and the minimum runoff occurred in September 1941 when the stream was dry for the entire month.

TABLE IX

TOTAL RUNOFF BY MONTHS AND YEARS
CANE CREEK WATERSHED

Values in Inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1940		3.30	4.35	1.77	1.07	0.13	0.43	0.26	0.03	0.03	0.37	0.60	
1941	0.40	0.10	0.12	0.08	0.04	0.01	0.07	0.08	0.00	0.02	0.12	0.11	1.15
1942	0.32	1.03	1.60	1.79	0.12	0.22	0.14	0.14	0.22	0.31	0.16	2.09	8.14
1943	0.35	0.46	2.71	0.55	0.60	0.25	0.31	1.46	0.89	0.25	0.94	0.75	9.52
1944	1.32	4.55	3.24	3.96	0.78	0.36	0.34	0.97	0.55	1.07	1.08	4.94	23.16
1945	3.49	3.58	2.34	1.89	2.42	2.14	0.29	0.40	0.31	0.84	3.04	2.30	23.04
1946	8.72	3.00	2.64	0.56	0.54	0.26	1.24	0.71	0.94	0.28	1.40	1.44	21.75
1947	4.87	0.49	1.60	1.95	2.00	0.41	0.08	0.08	0.11	0.43	1.14	0.98	14.14
1948	2.36	10.17	4.65	2.55	0.37	0.26	0.46	0.15	0.26	0.30	3.09	3.90	28.52
1949	5.10	2.23	3.47	1.98	2.03	2.16	1.36	1.86	0.76	1.36	1.30	4.92	27.68
1950	10.22	4.75	3.93	0.83	1.48	1.00	0.49	0.83	1.61	0.49	1.73	1.98	29.34
1951	4.37	5.00	2.58	2.58	0.45	0.98	1.76	0.32	0.37	0.23	3.36	8.53	30.53
Total	41.52	38.66	33.23	20.49	11.95	8.20	6.97	7.26	6.05	5.61	17.73	31.64	229.31
Ave.	3.78	3.22	2.77	1.71	1.00	0.68	0.58	0.60	0.50	0.47	1.48	2.64	19.43

TABLE X

SURFACE RUNOFF BY MONTHS AND YEARS
CANE CREEK WATERSHED

Values in Inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1940		2.88	3.68	1.29	.74	.03	.31	.17	.00	.00	.29	.45	
1941	.30	.01	.04	.04	.00	.01	.04	.06	.00	.01	.08	.05	.64
1942	.21	.87	1.38	1.65	.02	.12	.06	.04	.14	.23	.01	1.86	6.59
1943	.12	.20	2.40	.28	.35	.03	.16	1.17	.58	.00	.60	.35	6.24
1944	.68	3.92	2.56	3.31	.36	.11	.13	.71	.24	.71	.64	4.29	17.66
1945	2.61	2.93	1.74	1.42	1.89	1.74	.05	.20	.17	.49	2.53	1.70	17.47
1946	8.05	2.42	2.03	.13	.21	.03	.92	.44	.71	.06	1.00	1.00	17.00
1947	4.22	.04	1.03	1.41	1.61	.14	.01	.06	.10	.39	.72	.53	10.26
1948	1.73	9.38	3.91	1.96	.03	.04	.26	.03	.22	.09	2.64	3.01	23.30
1949	4.17	1.45	2.51	1.08	1.38	1.46	.73	1.13	.18	.69	.43	2.92	18.13
1950	8.20	3.16	2.54	.10	.78	.45	.03	.40	1.04	.04	1.11	1.31	19.16
1951	3.63	4.12	1.80	1.85	.00	.58	1.32	.01	.08	.08	2.74	7.00	23.21
Total	33.92	31.38	25.62	14.52	7.37	4.74	4.02	4.42	3.46	2.79	12.79	24.47	169.50
Ave.	3.08	2.52	2.14	1.21	0.61	0.39	0.33	0.37	0.29	0.23	1.06	2.04	14.27

TABLE XI

GROUND-WATER RUNOFF BY MONTHS AND YEARS
CANE CREEK WATERSHED

Values in Inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1940		.42	.67	.48	.33	.10	.12	.09	.03	.03	.08	.15	
1941	.10	.09	.08	.04	.04	.00	.03	.02	.00	.01	.04	.06	.51
1942	.11	.16	.22	.14	.10	.10	.08	.10	.08	.08	.15	.23	1.55
1943	.23	.26	.31	.27	.25	.22	.15	.29	.31	.25	.34	.40	3.28
1944	.64	.63	.68	.65	.42	.25	.21	.26	.31	.36	.44	.65	5.50
1945	.88	.65	.60	.47	.53	.40	.24	.20	.14	.35	.51	.60	5.57
1946	.67	.58	.61	.43	.33	.25	.32	.27	.23	.22	.40	.44	4.75
1947	.65	.45	.57	.54	.39	.27	.07	.02	.01	.04	.42	.45	3.88
1948	.63	.79	.74	.59	.34	.22	.20	.12	.04	.21	.45	.89	5.22
1949	.93	.78	.96	.90	.70	.70	.63	.73	.58	.67	.87	1.10	9.55
1950	2.02	1.59	1.39	.73	.70	.55	.46	.43	.57	.45	.62	.67	10.18
1951	.74	.88	.78	.73	.45	.40	.44	.31	.29	.15	.62	1.53	7.32
Total	7.60	7.28	7.61	5.97	4.58	3.46	2.95	2.84	2.59	2.82	4.94	7.17	59.81
Ave.	0.69	0.61	0.63	0.50	0.38	0.29	0.25	0.24	0.22	0.24	0.41	0.60	5.06

CHAPTER VI

FLOODS

Flood Heights Before TVA

Very little is known about the flood heights in the Cane Creek area before TVA investigations began. According to elderly residents in the area, the largest flood in the past 50 years occurred on March 16, 1919. It is thought that the January 1946 flood, the largest flood since 1940, was approximately one foot lower than the flood of March 1919.

Other information obtained by the TVA in 1936 indicates that large floods occurred in March 1897, December 1926, January 1935, and January 1937 (4).

Flood Records, 1940-1951

Stream flow records on Cane Creek for the past 12 years show that bankfull stage of 7.5 feet has been equaled or exceeded 210 times. This is an average of 17 floods per year. Only one flood exceeded bankfull stage in the very dry year of 1941, while 30 floods exceeded this stage in 1951. Table XIII shows the monthly and annual floods equaling or exceeding overbank stage.

The average for 1940-1943, a period of low to moderately low rainfall, was approximately six floods per year, while the average for 1944-1951, a period of average to heavier than average rainfall, was approximately 23 floods per year. The greater frequency in the latter

TABLE XII

MONTHLY DISTRIBUTION OF FLOODS EQUALING
OR EXCEEDING BANKFULL STAGE OF 7.5 FEET

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1940		1	2	1	1								5
1941	1												1
1942		1	1	1						1		1	5
1943			5	1				3	2		1		12
1944	1	5	3	4	1			1		1	2	4	22
1945	1	4	3	2	4	4		1		1	4	2	26
1946	4	4	4				2	1	1		2	2	20
1947	3		2	1	3					1	1	1	12
1948	2	5	6	2			2		1		2	4	24
1949	5	2	6	1	2	1		2	1	2	1	1	24
1950	8	1	7	1	3	1		2	2		2	2	29
1951	4	5	3	3		2	3				4	6	30
Total	29	28	42	17	14	8	7	10	7	6	19	23	210

years resulted not only from increased rainfall during these years, but also from the rapidly decreasing capacity of the channel.

Table XII also brings out the frequency of floods during the crop season, May through October. Fifty-two floods, 26 percent of the total occurred during the growing season.

March has the highest flood frequency with 42 floods, 19 percent of the total while October has the lowest frequency with six floods, 3 percent of the total.

Table XIII shows the ten highest floods during the period of stream flow record, 1940-1951, and Table XIV shows the highest monthly flood for the same period. These tables show that the highest floods occur during the dormant seasons. The highest crop season flood ranked number ten with the second highest ranking number twenty.

The wide difference in discharge shown in Table XIII for nearly equal stages of January 8, 1946, and January 3, 1951, illustrates again the effect of channel deterioration. This situation greatly complicates any study of flood heights and frequencies on Cane Creek.

TABLE XIII

TEN HIGHEST FLOODS, 1940-1951
CANE CREEK NEAR CHESTERFIELD

Date	Crest Stage feet	Discharge cfs
November 19, 1948	9.25	1240
January 3, 1951	9.14	988
January 8, 1946	9.13	5330
January 10, 1950	9.12	940
December 14, 1951	9.10	900
December 12, 1949	9.07	850
January 13, 1951	9.05	805
December 4, 1951	8.99	718
February 13, 1948	8.98	3650
July 10, 1951	8.98	706

TABLE XIV

MONTHLY MAXIMUM FLOOD HEIGHTS, 1940-1951
CANE CREEK NEAR CHESTERFIELD

Date	Crest Stage feet	Discharge cfs
January 3, 1951	9.14	988
February 13, 1948	8.98	3650
March 13, 1950	8.95	670
April 27, 1951	8.95	670
May 7, 1950	8.66	410
June 4, 1950	8.48	330
July 10, 1951	8.98	706
August 31, 1950	8.50	330
September 2, 1950	8.76	480
October 6, 1944	8.03	350
November 19, 1948	9.25	1240
December 14, 1951	9.10	900

CHAPTER VII

DROUGHTS

In the Cane Creek vicinity, rainfall during the growing season is normally adequate in amount, but frequently its distribution is uneven which interferes with its full utilization. Since 1917, severe droughts have occurred in 1925, 1930, and 1936 which caused pastures to turn brown, and caused complete failure of some crops (4).

For purposes of analysis, a period of rainfall deficiency is assumed to begin on the eleventh day following a rain of one-half inch in 24 hours, and to continue until rainfall of one-half inch again occurs in 24 hours.

The record of rainfall at Perryville, Tennessee, near the mouth of the Beech River was studied for periods of deficient rainfall by the Hydraulic Data Branch in April 1947 in preparing the report "Rainfall Data for Irrigation Studies." This station is considered representative of the area surrounding the Cane Creek watershed (4). Records covering the 30-year period 1917 and 1946 were investigated in this study.

From this study, it was evident that every growing season was characterized by deficient periods of varying lengths. The year 1925 had the longest period of rainfall deficiency with 114 days. Other unusually dry years were 1930, 1931, 1932, 1934, and 1936 (4).

Table XV shows the percent of time with rainfall deficiency at Perryville, Tennessee. Analysis of these data by months shows that

TABLE XV

PERCENT OF TIME WITH RAINFALL DEFICIENCY DURING THE GROWING SEASON
PERRYVILLE, TENNESSEE

April	33.5
May	34.0
June	37.9
July	45.2
August	38.3
September	47.2
Growing Season	39.4

deficient periods vary from 33.5 percent in April to 47.2 percent in September, indicating a trend toward greater deficiencies as the growing season progresses.

Table XVI shows the number of days of deficient rainfall to be expected according to several time intervals of occurrence.

Effect of Droughts on Crops

The three years, 1925, 1936, and 1930, experienced the greatest seasonal duration of rainfall deficiency at Perryville in the 30-year period 1917 to 1946. The effect of drought conditions on crops during those years is summarized from monthly reports of the U. S. Weather Bureau publication "Climatological Data" (11).

During the growing season of 1925, there were 114 days of rainfall deficiency at Perryville, and the accumulated departure from normal rainfall from April through August was over 12 inches. Forest fires raged unchecked, pastures suffered heavily, and millions of dollars worth of crops, particularly corn, in the State of Tennessee were ruined. There were heavy losses in tobacco and truck crops. Cotton, an exception, declined seriously in the late summer but improved with rains in the middle of September to yield a fairly good crop.

The 1936 growing season was alternately wet and dry with 112 days of rainfall deficiency. The drought was broken into segments by good rains in the first half of June and a storm in the first week of July. In general, crop conditions followed the rainfall cycle, and pastures were alternately brown and green. Much of the corn and

TABLE XVI

DEFICIENT DAYS FOR GROWING SEASON
PERRYVILLE, TENNESSEE

Interval of Occurrence	Days with Deficient Rain
1 year in 20	110
1 year in 4	83
1 year in 2	70
3 years in 4	55
Every year	30

tobacco survived, though gardens deteriorated rapidly and many truck crops failed. The cotton yield was about two-thirds of normal.

There were 99 days of rainfall deficiency in the growing season of 1930, and the accumulated departure from normal rainfall was -5.33 inches. After a late start because of dry conditions in April, planting was started in May. The following three months were hot and dry, and all crops deteriorated steadily. The bulk of the upland crop was ruined, pastures dried up, and truck crops were greatly reduced both in quantity and quality. Trees became discolored and shed many leaves. Tobacco was cut weeks ahead of normal schedule but yielded a generally good crop. Late-growing crops were revived by rain in September, and late vegetables were rather plentiful (4).

CHAPTER VIII

GROUND WATER

The Cane Creek watershed lies in the outcrop area of the Selma clay formation and the Coon Creek tongue of the Ripley formations.

The Selma clay was deposited under marine conditions in water of sufficient depth to keep the bottom free of wave action. Clay and sand were brought to this sea and were deposited along with lime, so that the formations consist of chalky clay and argillaceous sand. When wet the unweathered clay is slate blue. Its weathered surfaces are from grayish white to gray and are strewn with fossils. This formation is approximately 150 feet thick (12).

Though the Selma formation is slightly porous, it is not a water-bearing formation. Very small quantities of water will seep out of it, but this water is highly charged with mineral matter, has an unpleasant taste, and is poor water for any purpose (12).

The Coon Creek tongue of the Ripley formation was deposited by a sea as it receded, advanced, and receded again. This formation consists, in this area, of black to bluish-green marl. The marl is composed of quartz, sand grains, glauconite, small flakes of mica, and fragments of shells cemented together by fine calcareous material. This formation is approximately 100 feet thick (12).

The water-bearing characteristics of the Coon Creek tongue of the Ripley formation are very similar to the water-bearing characteristics of the Selma formations (12).

The most recent deposit in the Cane Creek watershed is the alluvium which forms the bottom and flood plains of the present stream system. This alluvium consists of material derived by erosion from adjacent formations and ranges up to 100 feet in thickness (8).

The variable character of this formation makes it a poor source for a large supply of water, but small quantities may be developed almost anywhere.

From the above discussion it may be concluded that the Selma formation and Coon Creek tongue of the Ripley formation are very poor sources of ground water for any purpose, while small quantities of ground water may be obtained from the alluvium. However, a limited supply of water for domestic and farm use may be obtained by drilling through the Selma clay and Coon Creek tongue formations into the Eutaw formation beneath.

CHAPTER IX

SEDIMENT

Erosion is a very serious problem in the Cane Creek watershed, especially in the hilly headwater area. Much of the topsoil has been lost by sheet erosion, and severely gullied areas are prominent throughout the steeper portions of the watershed. In addition to damage being done to the steeper areas by erosion, the creek bottoms are being covered with sand, and the channels of the streams are being filled by deposition. As the channels are filled, their carrying capacity is decreased, thus aggravating the already serious flood problem (4).

There have been no sediment measurements made over an extended period of time in this area. However, sediment measurements were made on Cane Creek near Chesterfield, West Fork Cane Creek near Shady Hill, and East Fork Cane Creek near Shady Hill during the storm of March 27-29, 1951. Table XVII shows the amount of suspended sediment carried by Cane Creek and these tributaries as a result of this one storm.

Table XVII indicates that 35 tons of sediment was deposited between the point of confluence of East Fork Cane Creek and West Fork Cane Creek and the measuring station on Cane Creek. This shows that a fairly large percentage of the eroded material is redeposited in the flatter, downstream reaches. There it creates additional problems by covering the bottom lands and by clogging the channels of the streams.

During the same storm, the Henderson County experimental watershed had a suspended sediment loss of only 3.2 tons per square mile.

TABLE XVII

SUSPENDED SEDIMENT LOADS
STORM OF MARCH 27-29, 1951

Location	Drainage Area in Square Miles	Suspended Sediment	
		Tons	Tons per Square Mile
Cane Creek	22.7	491	21.6
East Fork Cane Creek	6.2	310	49.9
West Fork Cane Creek	7.8	216	27.9

Thus by the use of known conservation practices, it has been demonstrated that the tremendous erosion problem in this area can be reduced to a fraction of existing rates.

CHAPTER X

INFILTRATION

One of the most important elements in the evaluation of the effect of land and land use on storm runoff is the capacity of the land to absorb or infiltrate rainfall. Infiltration is usually defined as the passage of water through the soil surface into the soil, while percolation is defined as the movement within the soil. Therefore, these two phenomena are closely related in that infiltration cannot continue unimpeded unless percolation provides sufficient space in the surface layer for infiltrated water (6). However, in this study no attempt is made to distinguish between the two.

For the purpose of this study, the term "infiltration rate" generally refers to the average rate or infiltration index which is derived by considering an entire storm as a unit. Although the actual infiltration rate varies throughout a storm, being highest at the beginning, decreasing and becoming nearly constant as the duration of the storm lengthens, the use of the average rate in this study is justified as an approximation because the length of storms is sufficient so that the average rate may be used without serious error (4). Therefore, while the finite values of infiltration discussed below are not absolute, the conclusions reached with regard to trends may be accepted as valid.

In this study, 27 isolated storms were studied. The average infiltration rate for winter storms was determined to be approximately

0.12 inch per hour, while the average infiltration rate for summer storms was 0.41 inch per hour. However, the minimum observed summer infiltration rate of 0.17 of an inch per hour is considered more representative of the sustained rate which will be maintained during long, heavy rains and under wet soil conditions. Infiltration rates are higher during the summer as a result of normally drier soil and the effect of vegetation.

Table XVIII shows the average infiltration rates, the surface runoff, and the rainfall for the 27 isolated storms. Table XIX shows similarly computed infiltration rates for other watersheds in the Tennessee Valley.

Inspection of Table XIX shows that the infiltration rate for the Cane Creek watershed is considerably less than the infiltration rate for the Beech River watershed above Chesterfield. The lower infiltration rates of the Cane Creek watershed are thought to be due to the nature of the geologic formations in which this watershed is situated. The Cane Creek watershed lies in the outcrop area of the Selma clay formation and the Coon Creek tongue of the Ripley formation. Both of these formations are fairly impervious and non-water-bearing.

TABLE XVIII

RAINFALL, RUNOFF, AND INFILTRATION RATES
FOR SELECTED STORMS

Date	Rainfall inches	Runoff inches	Infiltration in/hr.
Winter			
1-2-44	1.54	0.59	0.04
2-8-44	3.07	1.14	0.09
11-19-44	1.23	0.24	0.08
1-18-45	0.71	0.24	0.11
3-20-45	1.47	0.49	0.11
12-13-45	1.16	0.37	0.09
3-6-46	2.05	0.64	0.20
12-11-46	1.44	0.31	0.10
3-23-47	0.90	0.13	0.18
1-12-48	0.81	0.09	0.08
4-8-48	1.92	0.58	0.20
4-13-48	1.72	1.12	0.04
3-9-49	1.46	0.46	0.14
11-12-49	1.09	0.33	0.28
2-22-50	0.61	0.12	0.08
11-24-50	1.40	0.72	0.05
Summer			
8-10-43	1.53	0.40	0.55
8-16-43	1.26	0.54	0.24
9-19-43	1.95	0.29	0.26
10-5-44	2.95	0.71	0.39
8-22-45	1.22	0.17	0.80
5-23-46	1.58	0.15	0.33
9-23-46	3.20	0.59	0.72
7-3-48	1.19	0.12	0.39
5-5-50	1.52	0.55	0.17
6-3-50	2.22	0.37	0.28

TABLE XIX

COMPARATIVE INFILTRATION RATES
CANE CREEK AND OTHER WATERSHEDS

Stream	Drainage Area Square Miles	Infiltration Rates	
		Summer inches per hour	Winter
Cane Creek near Chesterfield	25	0.17	0.12
Beech River above Chesterfield	115	0.23	0.17
Davidson River near Brevard	40	0.37	0.18
Swannanoa River above Biltmore	130	0.35	0.17
Pigeon River above Canton	133	0.33	0.17
Chestnee Creek at Dentville	116	0.19	0.09
Duck River at Shelbyville	481	-	0.04

CHAPTER XI

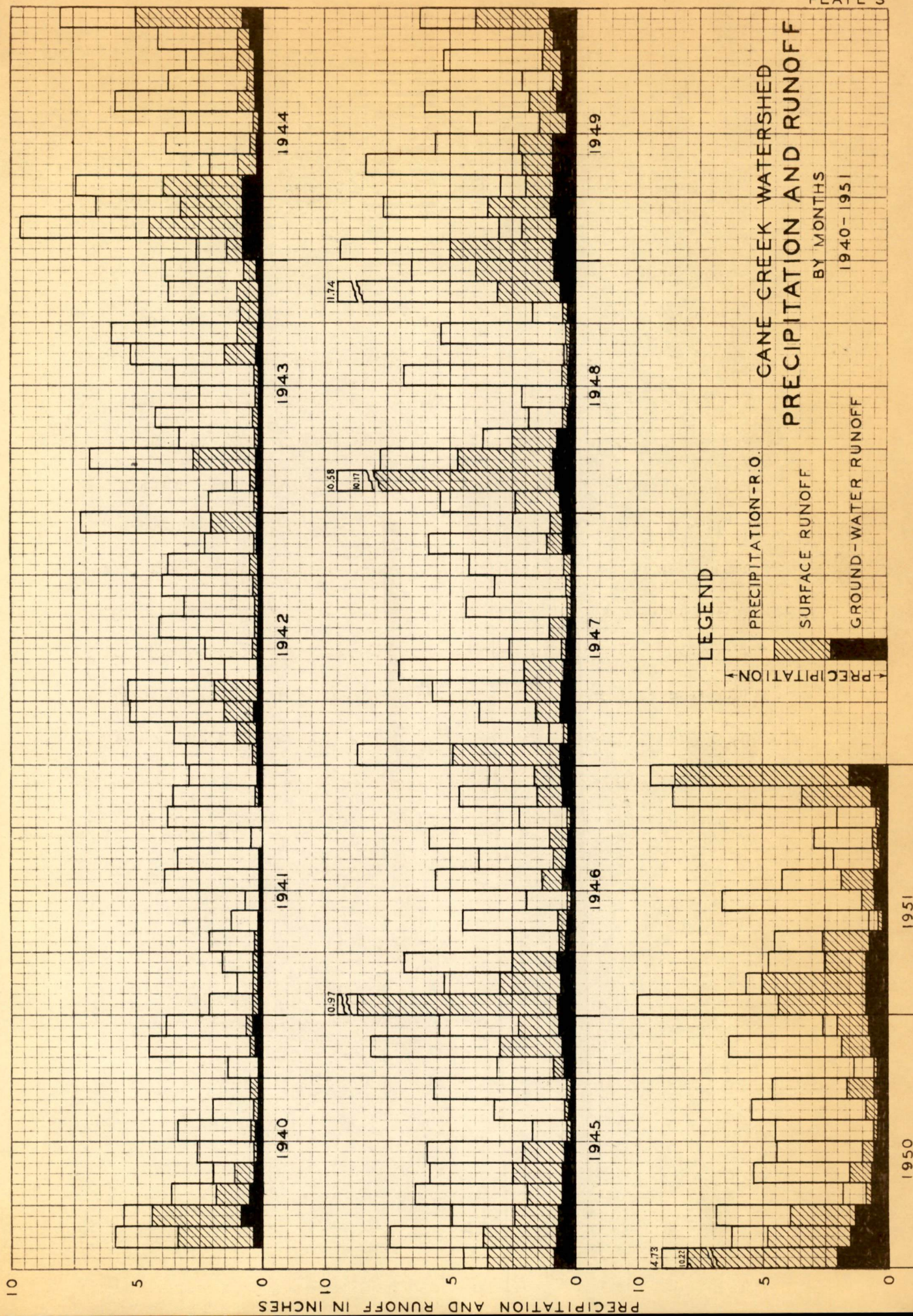
HYDROLOGIC RELATIONSHIPS

Analysis of hydrologic data is generally divided into two classes, one dealing with water-yield studies and the second with detailed studies of changes in the storm hydrograph. Water-yield studies are useful in determining the effect that changes in land cover have upon runoff. From these studies it is possible to determine whether such changes are limited to a particular month or season of the year and whether there has been a compensating shift from one month or season to another, such as a reduction in winter and spring flood flows balanced by an increase in low-water flow during the summer and fall. It is also possible to determine by water-yield studies whether there has been an interchange between surface and ground-water categories. Studies of storm hydrographs are important in indicating any changes that occur in the rate of frequency of peak discharge as well as volume and time distribution of storm runoff accompanying the land use changes (3).

Water Yield

Precipitation and Runoff by Months

Analysis of the bar graphs shown on Plate 3 presenting rainfall, total runoff, surface runoff and ground-water runoff by months shows that the rainfall has been very erratic. Apparently any particular month in a given year is likely to have the maximum rainfall or the



minimum rainfall for that year. This is illustrated by the fact that January ranked first five times and from seventh through eleventh six times during the twelve-year period. During the first six years, 1940-1945, January ranked sixth, seventh, eighth, ninth, tenth, and eleventh, while during the latter six years, 1946-1951, January ranked first five times and ninth one time. November ranged in rank from first through last, ranking first two times, third five times, tenth one time, and last one time. May ranked last three times, September two times and October two times. For average conditions, January is the wettest month, followed by March, with October the driest month.

Total runoff is more consistent than the rainfall, but in general, varies with the rainfall. A very wet month produces high total runoff and a very dry month produces low total runoff. During December, January, February, and March total runoff averages approximately 55 percent of the rainfall, while during June, July, August, September, and October total runoff averages approximately 20 percent of the rainfall.

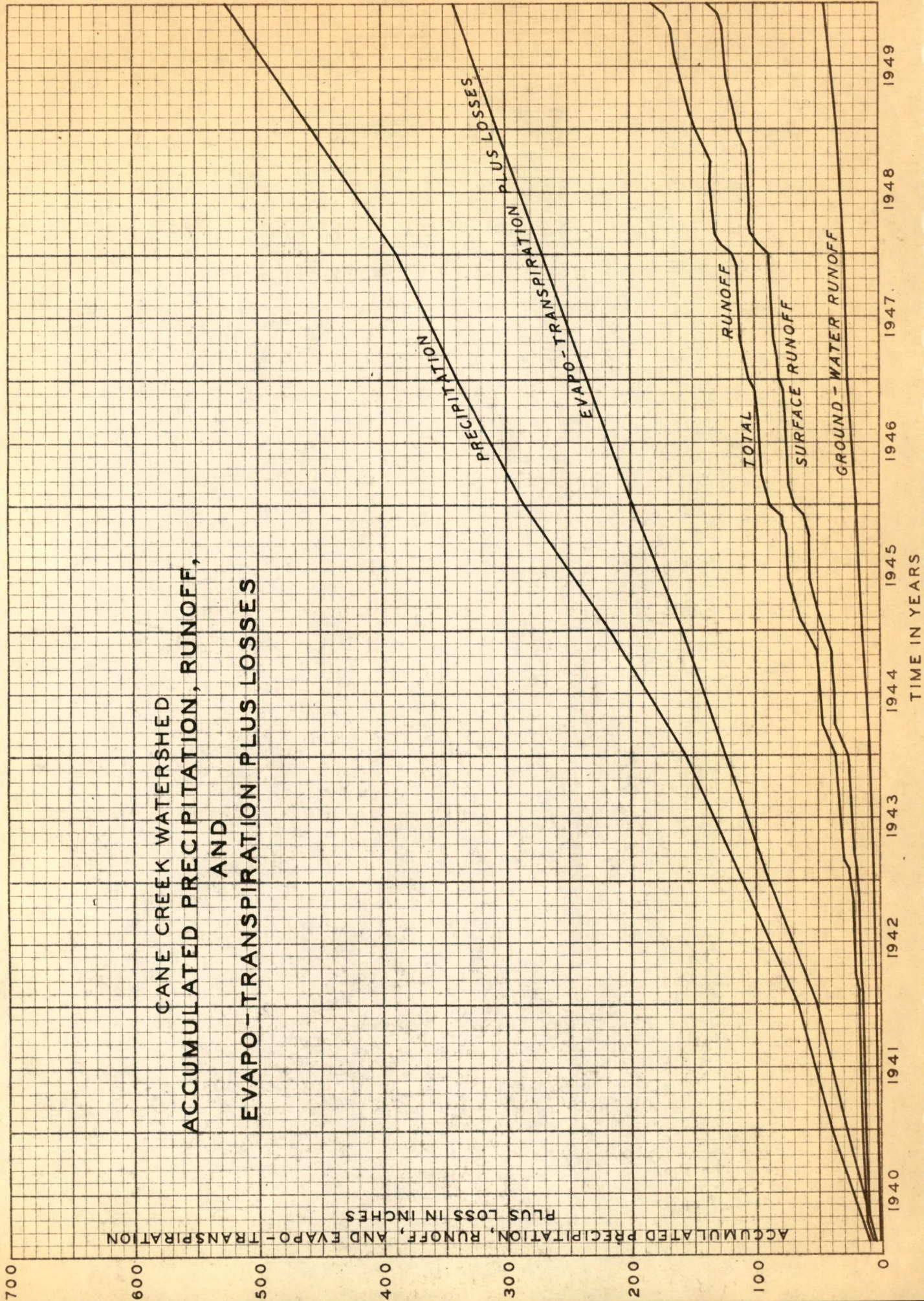
Surface runoff, in general, varies almost directly with the rainfall, a very wet month producing high surface runoff and a very dry month producing very little surface runoff. In the months of December, January, February, and March the surface runoff averages approximately 80 percent of the total runoff, while during the months of July, August, September, and October the surface runoff is approximately 50 percent of the total runoff.

Ground-water runoff is rather consistent varying very slowly from a high point in January to a low point in September and then slowly building back to the high point in January. The above is for average conditions, but, in general, the ground-water runoff followed this cycle rather closely varying only slightly during some periods of unusually wet or dry conditions. During December, January, February, and March the ground-water runoff composes about 20 percent of the total runoff, while during the months of July, August, September, and October the ground-water runoff averages approximately 50 percent of the total runoff.

Relationships Among Accumulated Precipitation, Total Runoff, Ground-water Runoff, and Evapo-transpiration plus Other Losses

Mass curve relationships and double-mass curve relationships develop the water-yield characteristics of the Cane Creek watershed in a form suitable for the study of possible changes in rates. Since these relationships do reflect changes in rates of water yield and since this study is to serve as a bench mark in the development of the Cane Creek watershed, these relationships are very important.

The graph of precipitation versus time, Plate 4, shows the rainfall deficient years of 1940-1943 by a slight flattening of the curve. From 1944 to the present, the curve approaches a straight line, except for alternating steep and flat segments. The steep segments indicate periods of heavy rainfall and the flat segments indicate periods of light rainfall. The curve as a whole has three distinct slopes, the period of very deficient rainfall, 1940-1941, having the flattest



slope, with the period of moderately deficient rainfall, 1942-1943, having an intermediate slope, and the period of average to high rainfall, 1944-1951, having the steepest slope.

The curve for evapo-transpiration plus other losses is the difference between precipitation and runoff. This curve approaches a straight line for the years 1942-1951, except for slight seasonal variations. For the first two years of record the curve is somewhat flatter because of the unusually deficient rainfall. The rainfall for 1941 was approximately 27 inches, while the average total evapo-transpiration plus other losses for the entire period was approximately 34 inches. This fact necessitated a change in the slope of the curve because the rainfall for 1941 was less than the average rate of evapo-transpiration plus other losses.

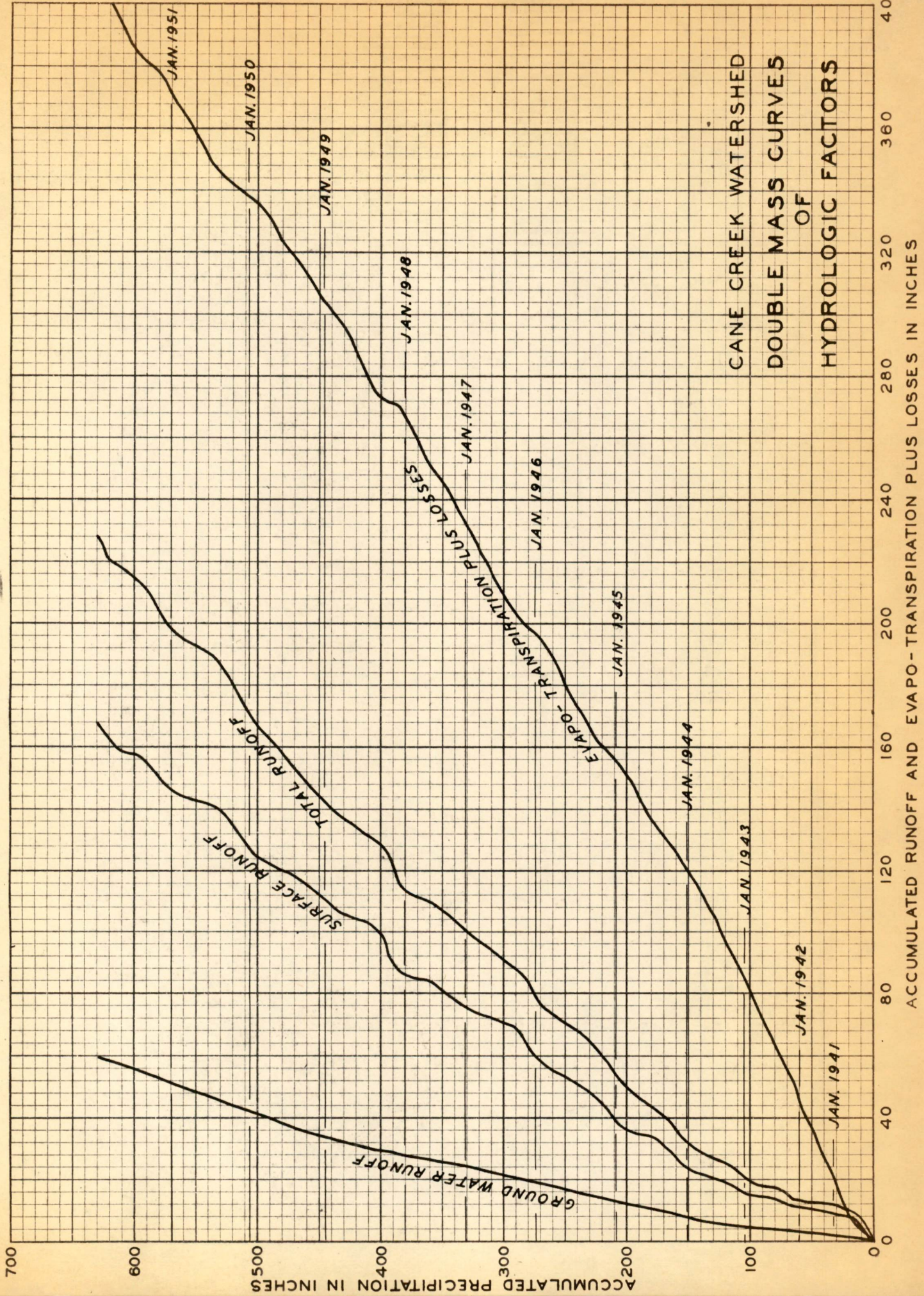
The curves of total runoff and surface runoff versus time are very similar. This indicates that total runoff is dependent upon surface runoff for an appreciable amount of its volume. Surface runoff for the entire period of record averages 74 percent of the total runoff. The curves for 1944 through 1951 have practically constant slopes except for rather drastic variations caused by wet and dry periods. The moderately dry years of 1942-1943 have a slight flattening of the curve indicating a runoff that is somewhat less than the succeeding years. The curves for 1940-1941 have a rather flat slope indicating a very drastic reduction in runoff when compared with the following years. In 1941 the total runoff was only 1.15 inches.

The mass curve of ground-water runoff versus time indicates the ground-water discharge is rather stable. The slight variations in the slope of the curve occurred during long periods of unusually wet or dry conditions. The pronounced flattening of the curve during 1940-1942 was caused by the unusually low rates of precipitation for those years, while the change in the slope during 1949-1950 was caused by the unusually high rates of precipitation during these years. Ground-water discharge averages approximately 26 percent of the total runoff for the entire period of record.

The double mass curve, Plate 5, represents another approach to the study of the interrelationships among precipitation, total runoff, surface runoff, ground-water runoff, and evapo-transpiration plus other losses. These relationships were established by plotting accumulated precipitation versus total runoff, surface runoff, ground-water runoff, and evapo-transpiration plus other losses.

The curve of precipitation versus evapo-transpiration plus other losses is approximately a straight line relation except for slight variations. The unusually steep segment in February 1948 was caused by a rainfall of 10.58 inches with a runoff of 10.17 inches. The slight flattening of the slope during the years 1940-1943 was caused by deficient rainfall.

The curves of precipitation versus total runoff, surface runoff, and ground-water runoff are approximately straight lines. The steep portions of these curves indicate reduced runoff. This reduced runoff may be attributed to deficient precipitation or to high total losses.



Storm Hydrograph

Storm Precipitation versus Surface Runoff

Plate 6 showing storm precipitation versus surface runoff illustrates the effect that antecedent moisture conditions have upon runoff during the winter season. Rainfall information was too uncertain to plot a similar relation for the summer season. In this relation surface runoff, the dependent variable, is plotted against storm precipitation, the most important independent variable. Wide variation of the individual storm points on the original plate indicated the importance of one or more additional variables.

The parameter of initial moisture based upon initial stream discharge resulted in a much higher degree of correlation. Insufficient information was available to use rainfall intensity as a parameter. Initial moisture index 1 represents the driest soil conditions, moisture index 2 represents intermediate conditions, and moisture index 3 represents the wettest conditions. Limits of the class were selected to give the highest degree of correlation. With these limits imposed approximately 25 percent of the storms were included in moisture index 1, 50 percent in moisture index 2, and 25 percent in moisture index 3.

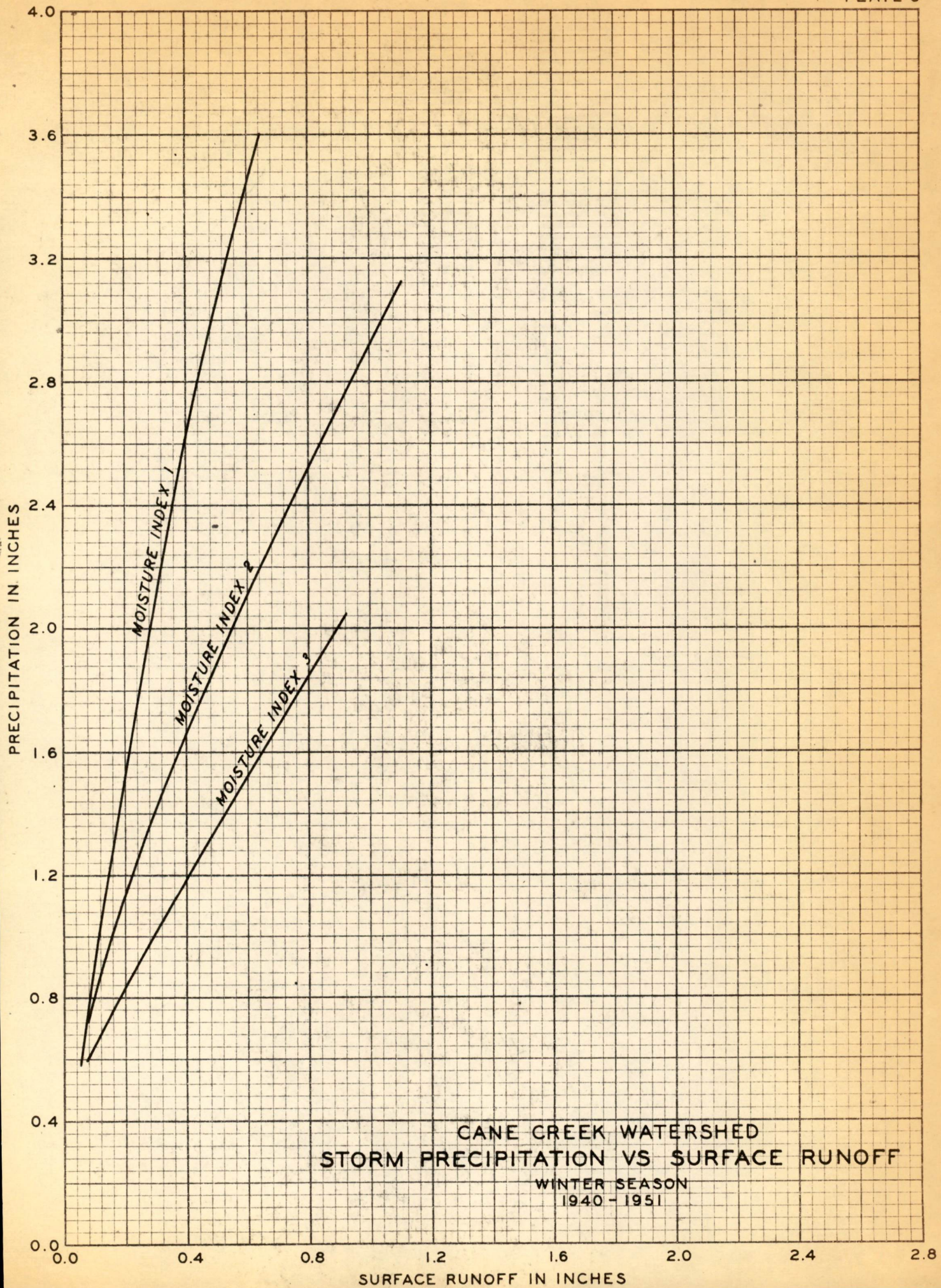
Surface runoff from the Cane Creek watershed is normally a considerable percentage of the rainfall normally experienced as shown by Table XX. This is especially true with antecedent moisture indices 3 and 2. A storm of two inches produces nine-tenths of an inch runoff with index 3 antecedent conditions. This same storm would produce a

TABLE XX

WINTER SURFACE RUNOFF

Runoff shown as a percentage

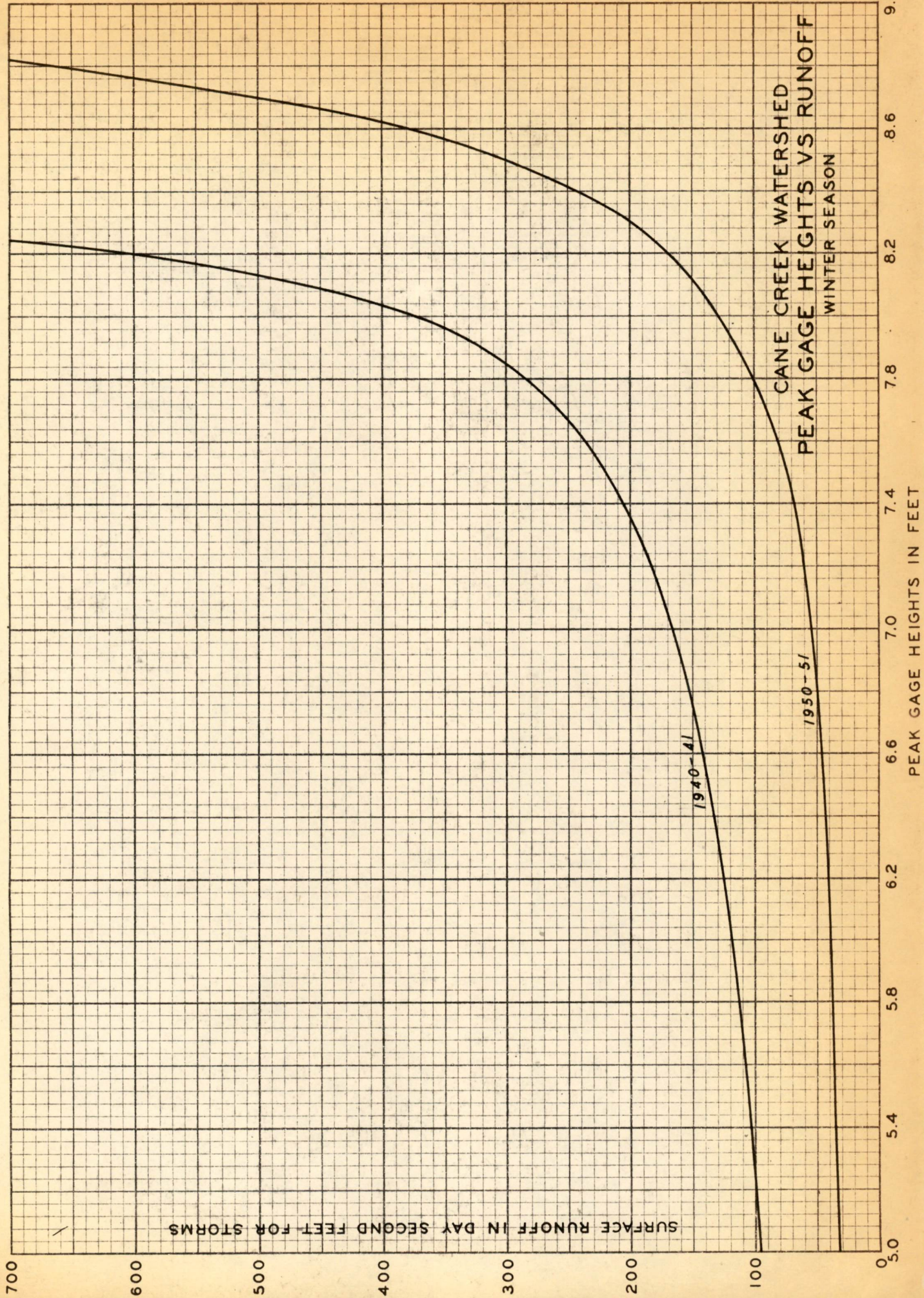
Precipitation Amount (inch)	Surface Runoff		
	Index 1	Index 2	Index 3
1	11	15	30
2	15	28	45
3	17	34	-

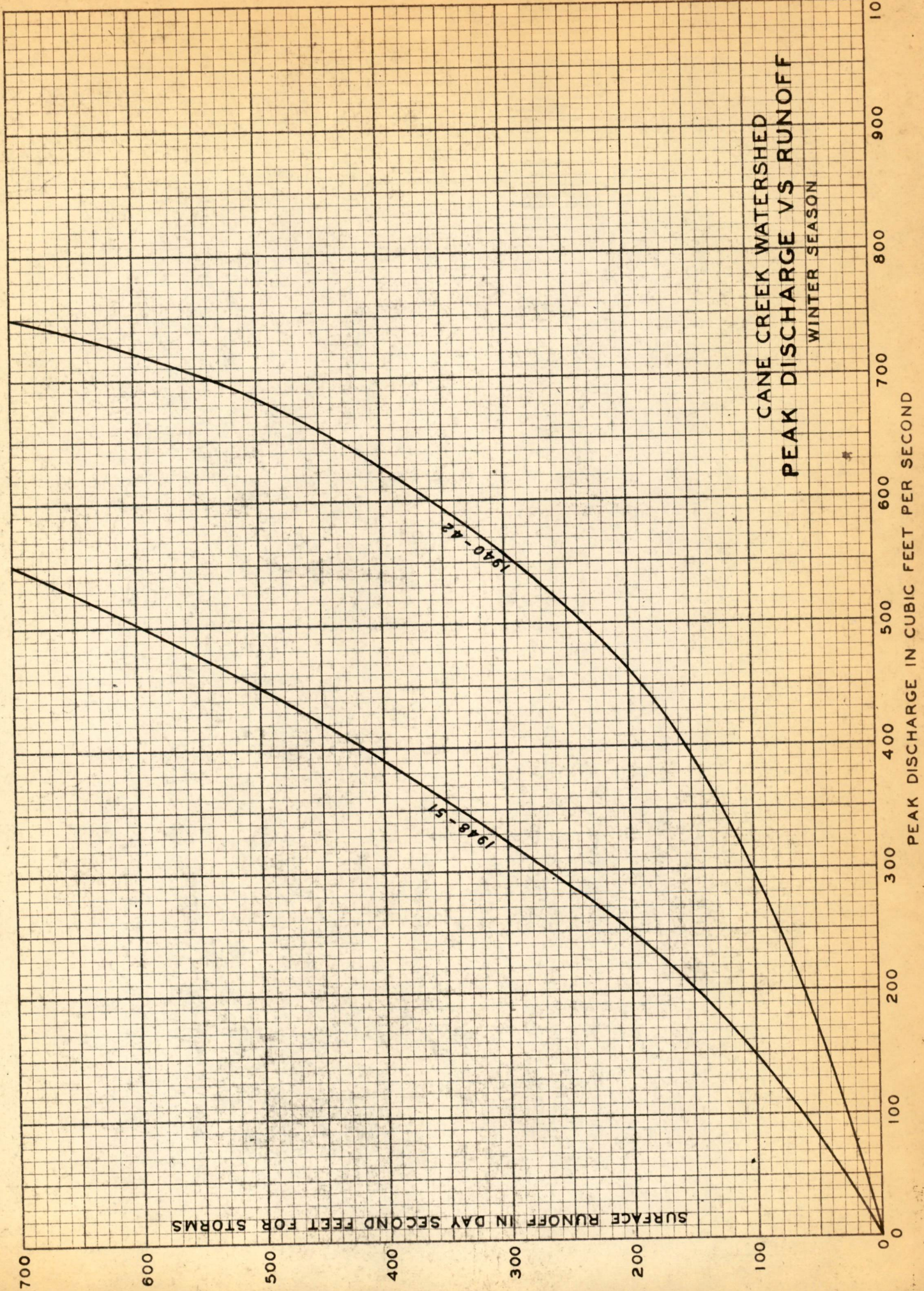


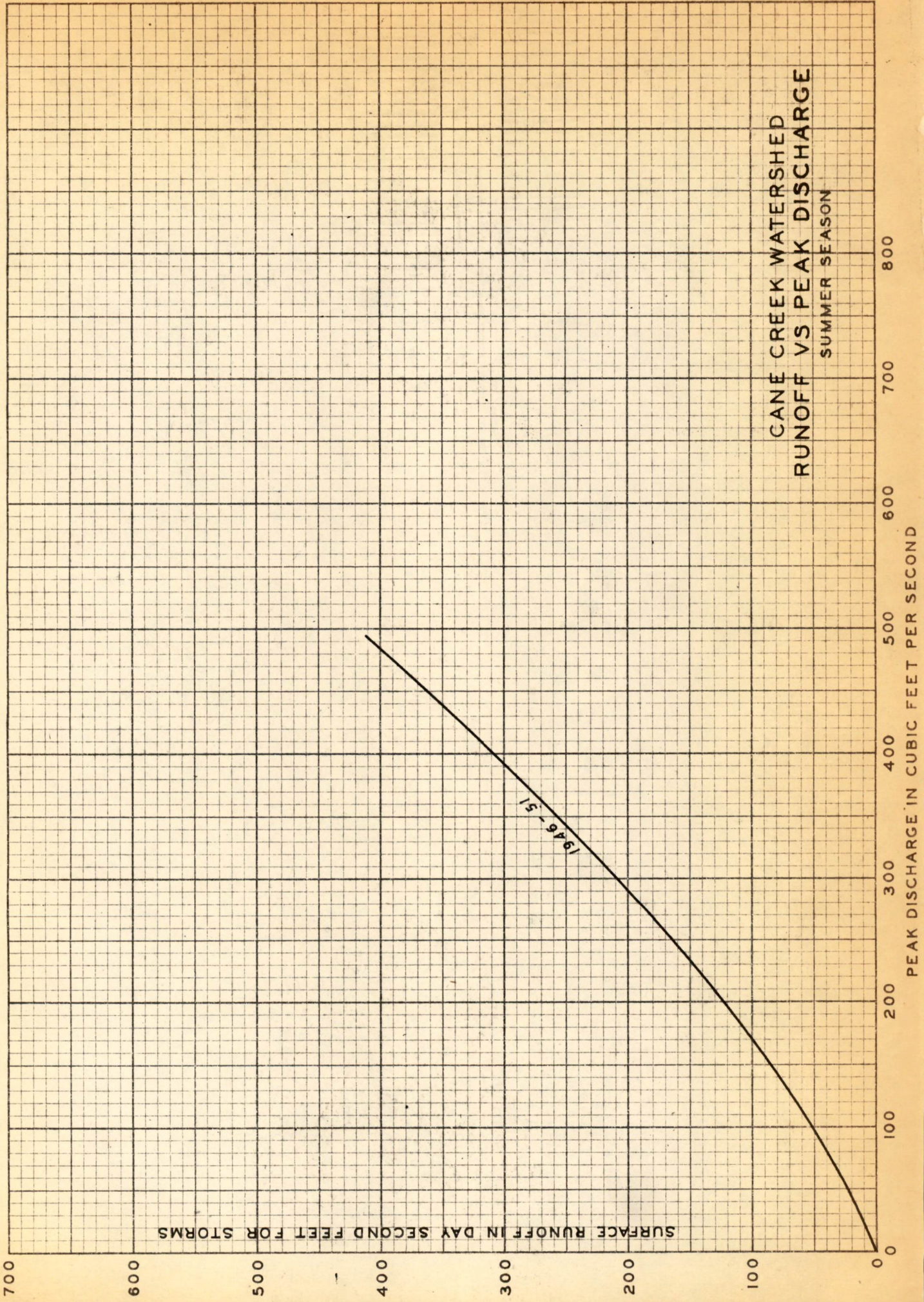
runoff of approximately six-tenths of an inch if preceded by intermediate moisture conditions.

Runoff Versus Peak Gage Height and Peak Discharge

The graphs of runoff versus peak gage height, Plate 7, and runoff versus peak discharge, Plate 8, for the winter season are general relations that illustrate graphically the deterioration of the Cane Creek channel. From these graphs the conclusion can be drawn that for a given gage height the runoff was much greater during the early periods of record than during the latter years, but conversely for a given peak discharge the runoff was much less during the early years than during the latter years. From these statements the conclusion can be drawn that for a given gage height the peak discharge was much greater during the early years of record than during the latter years. The graph of runoff versus peak discharge, Plate 9, for the summer season during the latter years of record indicates that for a given peak discharge less runoff is produced in the summer than in the winter. This condition can probably be attributed to added channel friction due to growing vegetation. Unfortunately, sufficient data were not available to plot a similar curve for the early years of record for the summer season. The few points that were available fell upon the winter curve indicating that for the early years of record the summer and winter curves would be practically identical. This assumption is further justified by the fact that the channel was new and in good condition during these early years with very little vegetation having had an opportunity to become established.







Peak Gage Heights and Discharge Frequencies

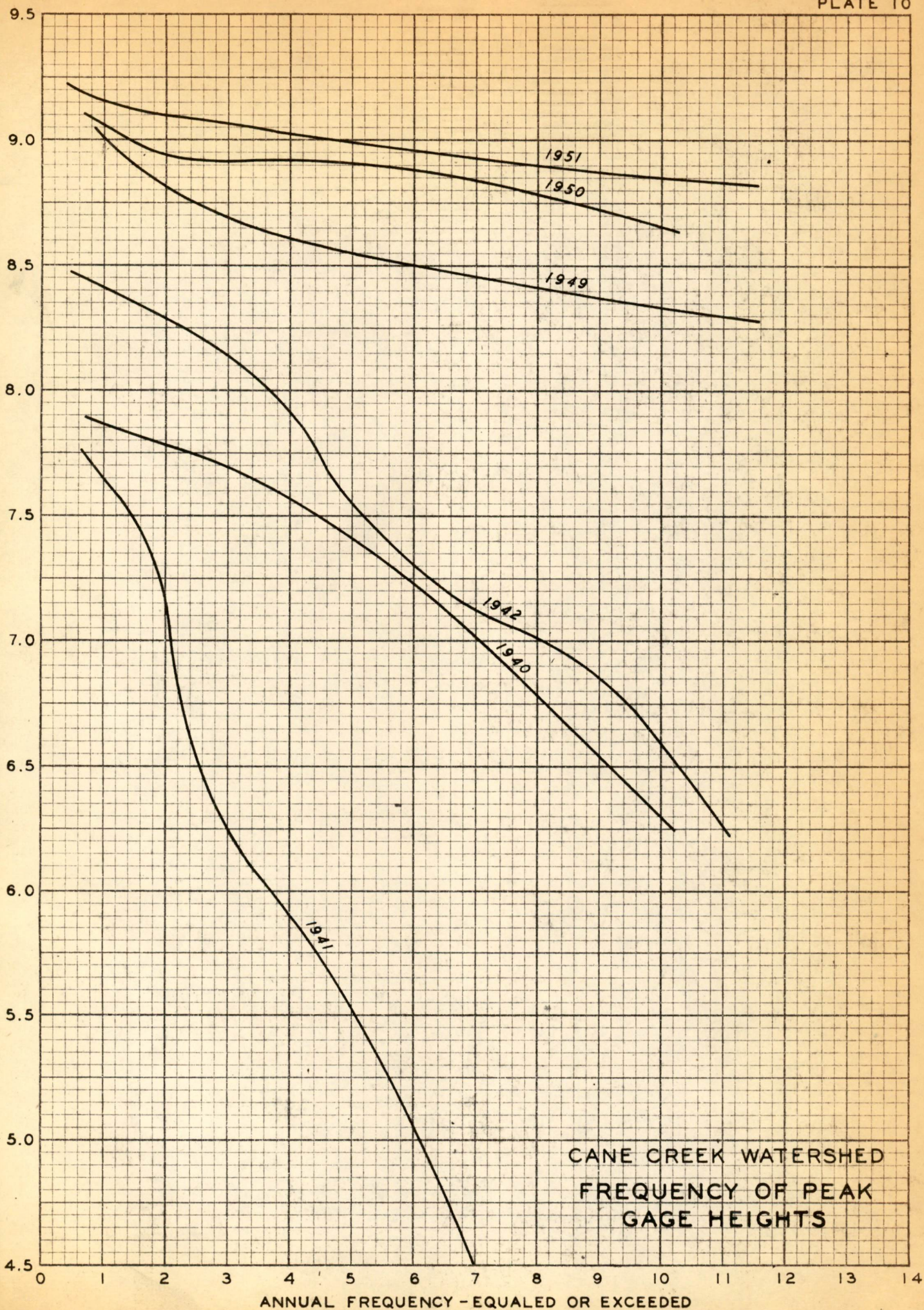
Plate 10 shows peak gage height frequency relations for the years shown. These years are the first three years and the last three years of the period of record. The intervening years were in excellent agreement with the years shown, depicting a gradual increase in gage height frequency with the passing of time.

This plate shows graphically the marked increase in gage height frequency caused by channel deterioration. During 1940 overbank stage of seven and one-half feet was exceeded only five times while during 1951 overbank stage was exceeded 30 times. Overbank stage was exceeded only once in 1941 but this year was a year of unusually low rainfall.

Peak discharge frequency curves were plotted for each year but no definite change was apparent with time. Apparently the amount and intensity of the storm rainfall has more effect on the production of peak discharges than does the condition of the channel.

Time Distribution of Runoff

To determine the effect of the deterioration of the Cane Creek channel upon the entire hydrograph of surface runoff, a study was made of the time distribution of surface runoff. To develop this relationship, the first three years of stream flow record and the latter three years of stream flow record were searched for isolated storms with a time to peak of approximately two to three hours and with no apparent rainfall during the period of recession. Storms which met these criteria were found to be confined primarily to the summer season, therefore, the conclusions reached bear that corresponding limitation.



The results are shown on Plate 11, the curves being essentially mass curve of storm runoff.

This plate shows a composite of a number of unit storms for the periods of 1940-1942 and for the period of 1949-1952. It is apparent that the time distribution of surface runoff from individual storms has changed materially during the period of record. This change in time distribution of surface runoff can be attributed to the deterioration of the Cane Creek channel. Surface runoff during the initial periods was rapid with 80 percent of the runoff passing the outflow station in approximated five hours. During the latter period approximately 13 hours was required to discharge 80 percent of the storm surface runoff. Table XXI shows the changes for various surface runoff percentages.

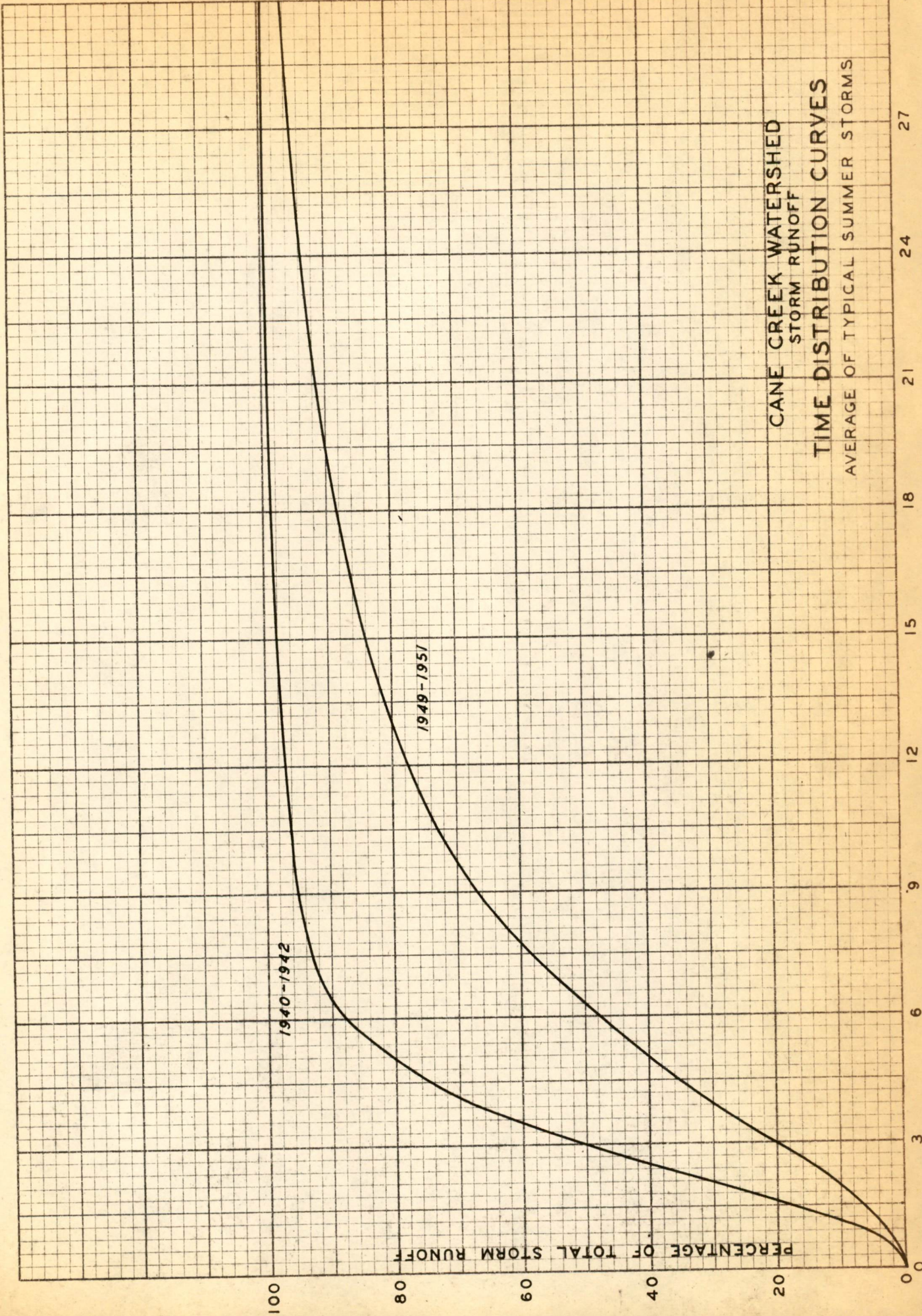
Surface Recession

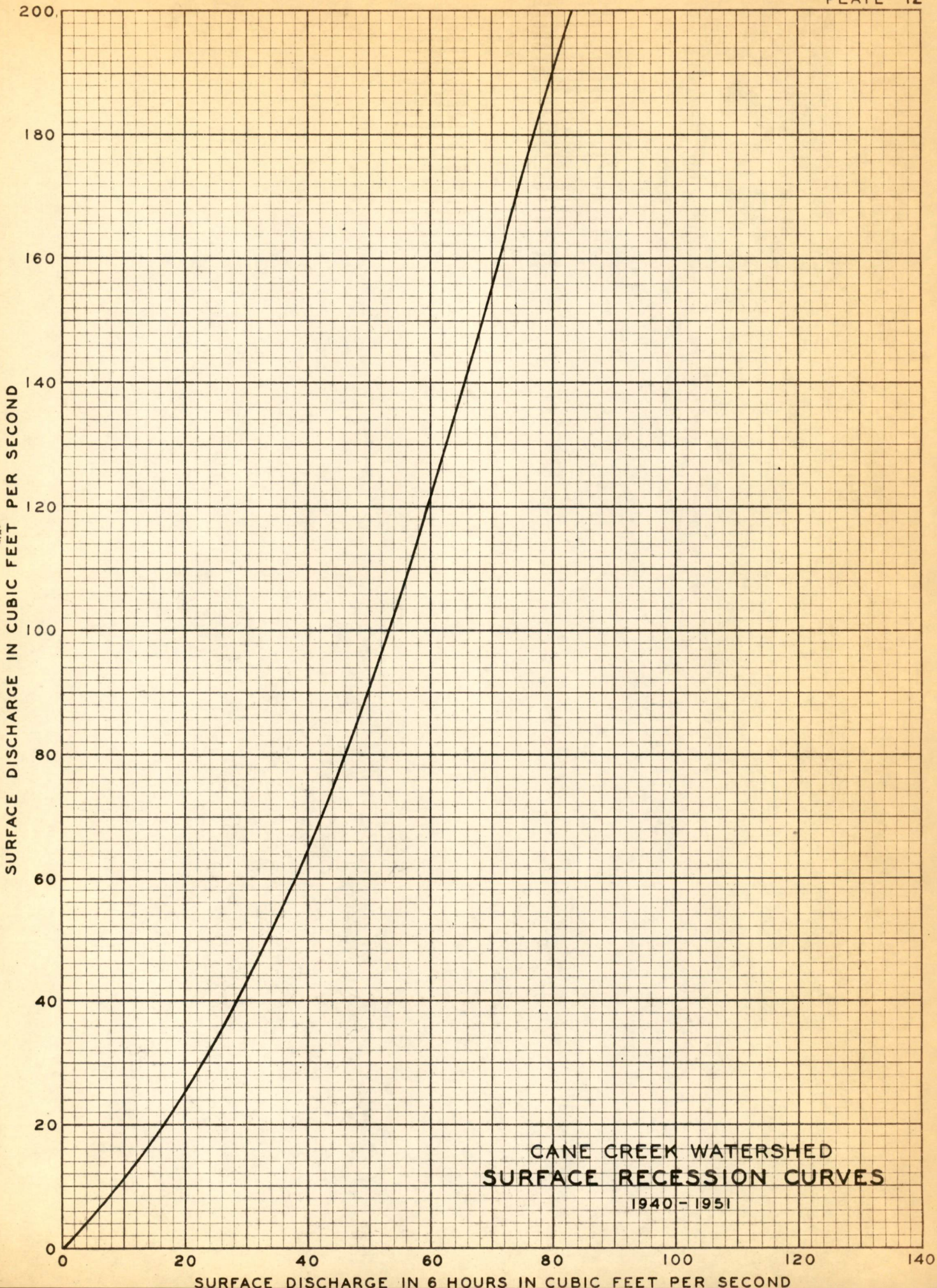
A means sometimes used in expressing modification in the recession phase of the storm hydrograph is surface recession curves of the type shown on Plate 12. In this particular case, however, it is thought that the time variation of the data was too great to afford adequate definition of the curve. Therefore, this curve should be used only as a general relationship. In general, curves of the type shown on Plate 12 are applicable to the final portion of the hydrograph during which the curvature is concave upward and they express the rate at which runoff drains out of the watershed channel system after overland flow has ceased.

TABLE XXI

TYPICAL TIME DISTRIBUTION
SUMMER SURFACE STORM RUNOFF

Percent of Surface Storm Runoff	Time to Runoff in Hours		Percent Time Increase
	1940-42	1949-51	
20	1.65	2.95	180
40	2.50	5.00	200
60	3.50	7.75	220
80	5.00	13.0	260





CANE CREEK WATERSHED
SURFACE RECESSION CURVES
1940-1951

Ground-water Recession

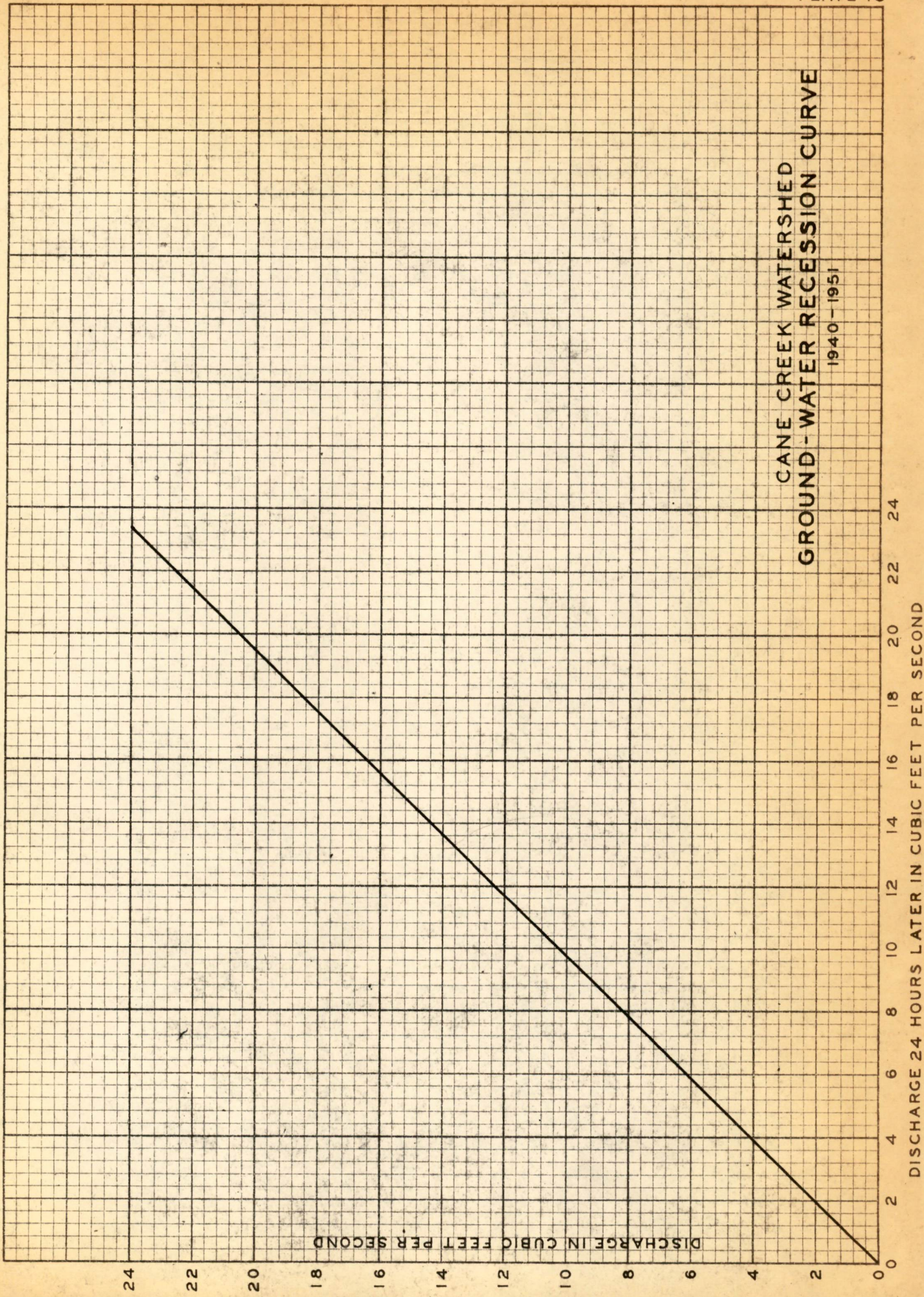
The ground-water recession curve for Cane Creek is shown on Plate 13. Ground-water recession curves define the rate at which water drains from underground storage. Individual points defining this curve were taken from the stream flow records for the indicated period at times of no surface discharge. The curve is a straight line for the range of discharges studied with a slope of 0.97. This slope, commonly referred to as the K factor, is the ratio of discharge to discharge 24 hours earlier.

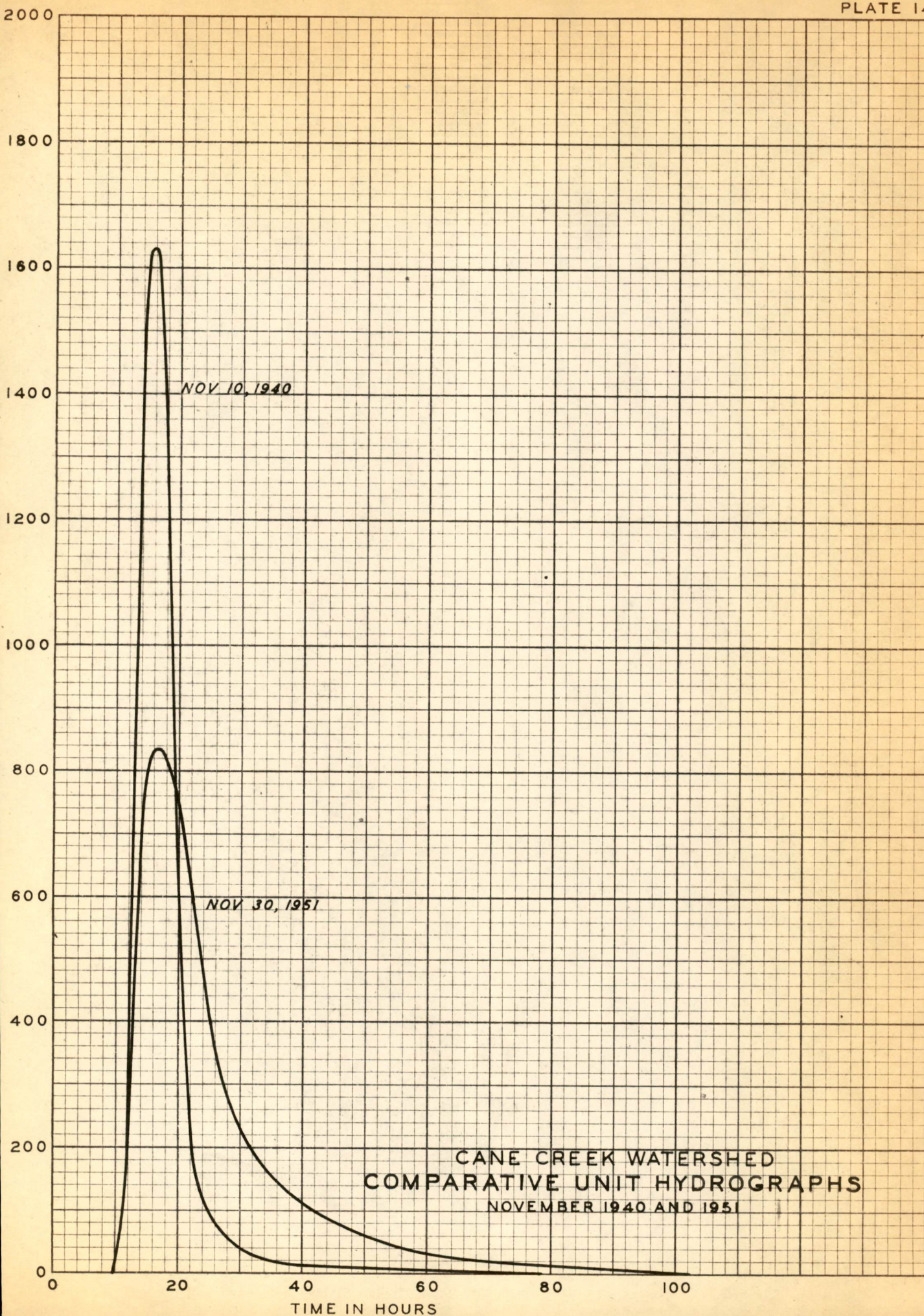
Evidently deterioration of the channel and change in channel storage has had very little effect upon the ground-water recession. This assumption can be made since the recessions studied came from the entire period of record and since there was very little scatter of the individual points. The consistency of the relation does indicate that no change has taken place in the zone of saturation which affects the rate of runoff delivery from underground sources.

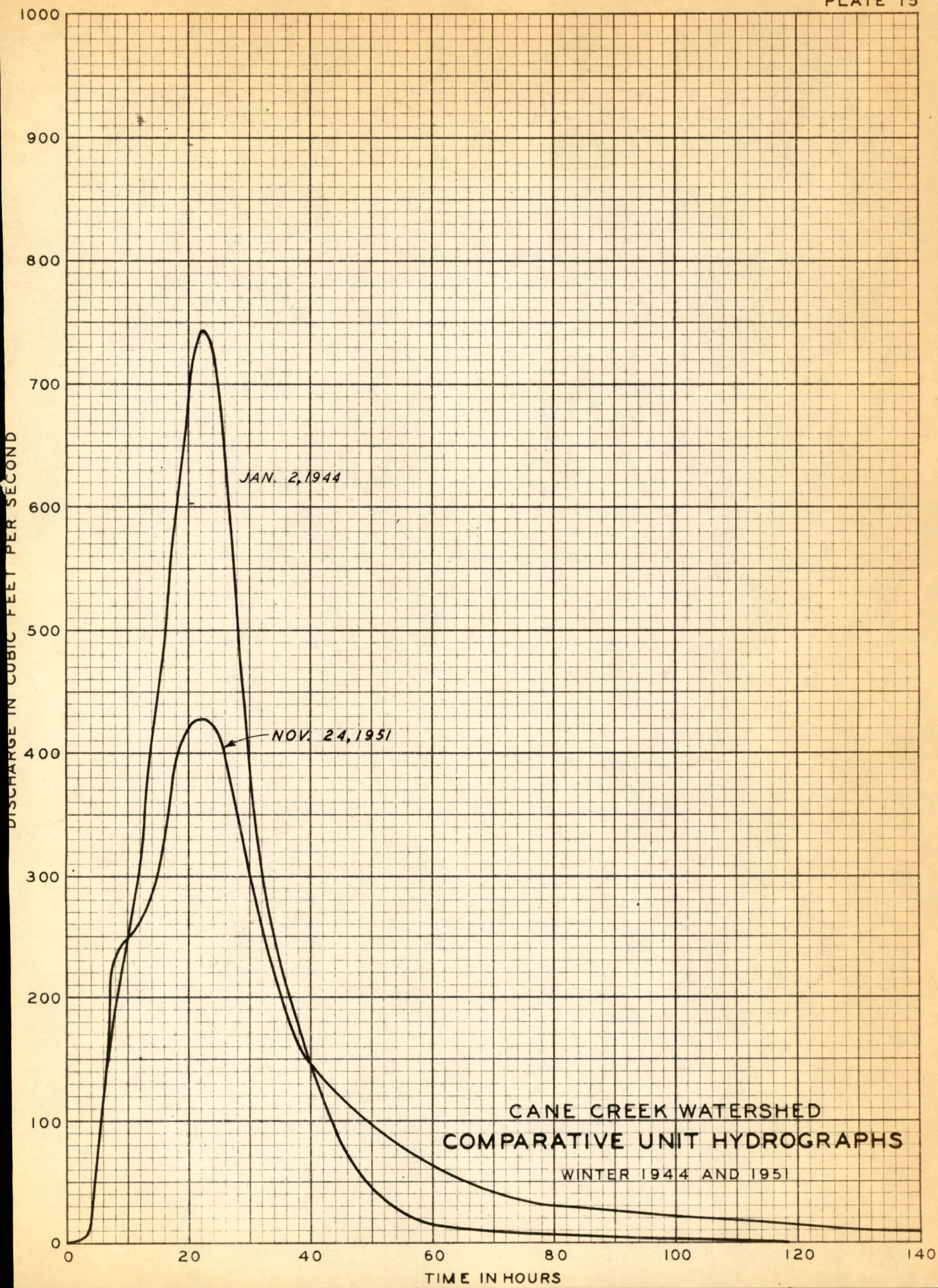
Comparative Storm Hydrographs

The standard unit hydrograph shown on Plates 14 and 15 illustrate the effect that the deterioration of the Cane Creek channel has had upon the storm hydrograph. To select these storms the entire period of record was searched for isolated storms that had similar characteristics and that occurred in different periods. The paired storms were found to have very similar initial flows, surface runoffs, storm rainfalls and storm durations. One pair matches the unit hydrograph of a storm that occurred in early November 1940 against a storm

CANE CREEK WATERSHED
GROUND-WATER RECESSION CURVE
1940 - 1951







that occurred in late October 1951 and the other pair matches the unit graph of a storm that occurred in early January 1944 with a storm that occurred in late November 1951. Therefore, any change that has occurred in the unit hydrograph may be attributed to the deterioration of the channel since no other major change has occurred within the watershed during the period of investigation.

The major observable changes in the unit hydrograph are the reduced, more rounded peaks and the longer recessions of the later storms, thus the net effect of the deterioration of the channel has been to retard the surface runoff.

Summary of Storm Hydrograph Studies

The changes in the storm hydrographs during the period of record could be attributed to improved land use or to deterioration of the Cane Creek channel. No measurements have been made to determine if land use changes have occurred, but general observations indicate no appreciable changes. Records are available on stream flow and channel deterioration. These records indicate more frequent high gage height peaks and lower discharge rates at present than during the early years of record. These are the type changes caused by deterioration of a stream channel. Improved land use would have caused both less frequent high gage height peaks and lower discharge rates. Therefore, any changes observed in the storm hydrographs during the period of record may be attributed to deterioration of the Cane Creek channel.

CHAPTER XII

SUMMARY

In Chapter I of this thesis the purpose was stated and the method to be followed in achieving this purpose was outlined. The outline was followed rather closely in working toward the desired results.

During the course of this study, analyses were made of the precipitation, stream flow, floods, droughts, ground water, sediment, infiltration, and various hydrologic relationships. It is thought that more and possibly better hydrologic relationships could have been derived had better rainfall information been available. However, it is felt that the hydrologic characteristics of the Cane Creek watershed have been established. Therefore, the purpose of this study has been fulfilled.

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