PATTERNS OF SPRING RUNOFF - THAMES RIVER ONTARIO /

- D. N. McMullen *

1. Introduction

The Thames River in Southwestern Ontario (fig. 1) is prone to flooding during the spring months. Loss of life and serious property damage have occurred on a number of occasions. The runoff pattern and the associated meteorological conditions are examined herein for five of the most severe floods to ascertain their hydrometeorological components.

The discussion is directed primarily to the flood runoff from the upper part of the Thames basin, the hydrographs being for the stream gauge at Byron which is located just downstream of London. The drainage area at Byron is 1203 square miles.

2. Watershed Features

The watershed is drained by two main branches. These are the North Branch with a drainage area of 661 square miles and the South Branch with 529 square miles. The river is very flashy in nature, with high runoff rates particularly on the North Branch. The channel slope on the North Branch is fairly uniform at about 7 feet per mile while on the South Branch, the slope for the upstream portion is about 11 feet per mile but levels off to some 4 feet per mile downstream.

Apart from the city of London, population 180,000 and a few scattered towns, the watershed is a highly developed agricultural area.

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A recording stream gauge has been in operation at Byron since 1955. Prior to this, readings were taken manually twice a day using a tape and weight with more frequent readings during flood periods.

Fanshawe Dam, with a flood control storage of 30,000 acre-feet, is located on the North Branch, 7 miles above London. It was completed in 1953.

Estimates have been made of the effect of the reservoir, for the two hydrographs of 1960 and 1963, in order that this might be related to the uncontrolled flows of the earlier years.

As a matter of interest, two other flood control dams have been completed recently on this watershed. Wildwood Dam, with a storage of 20,000 acre-feet, is on Trout Creek, a tributary of the North Branch. It was completed in 1966. The Gordon Pittock Dam on the South Branch at Woodstock, storage 13,500 acre-feet, will be completed this winter.

The channel capacity of the Thames River downstream of the confluence at London is 35,000 c.f.s. Some flooding however may occur before this level is reached depending on the distribution of flow on each branch. This value is much above that prevailing in 1937 as the channel has been improved and the dikes raised over the ensuing years.

3. Floods

(i) April 1937

"The great flood that visited the Thames watershed on April 26-30th,1937, still remains the highest on record and, as regards destruction of property, is probably the most severe since the watershed was settled. It was caused by heavy and prolonged rains. The snow had melted completely and it is believed that the frost was out of the ground".*1

Intermittent rains occurred over the Thames basin during April, 1937 prior to the deluge on the 25th and 26th. One inch occurred in the first five days of the month, another inch in the middle of the month and between one, and one and one-half, inches on the 21st. All of which ensured a saturated watershed.

A deep low pressure area over the northern plain states on the 24th moved steadily north and eastward preceded by very warm moist air. Its position on the morning of the

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*1 Upper Thames Valley Conservation Report - 1952, Conservation Authorities Branch, Department of Energy and Resources Management, Toronto.

25th is shown in figure 7. A redevelopment and deepening of that part of the system just south of the Great Lakes resulted in a prolonged period of unusually heavy rain over Southern Ontario. The total storm rainfall for April 24-26th is shown in figure 1*2 while the mass curve of rainfall at London for this period is shown in figure 2.

The hydrograph of the flow at Byron for the period from April 21st to May 3rd is shown in figure 2. It will be noted from this chart how rapidly the flood was generated as a consequence of the heavy intense rainfall and how sharp a peak is developed from rain flood hydrographs on this watershed.

Though rainfall observations were only taken twice a day, in the morning and evening, from the data it is reasonable to presume that the period of heavy rain was from noon April 25th to midnight April 26th, some 36 hours. The streamflow, on the other hand, increased from a low flow of 5,000 c.f.s. at midnight April 25th, to a disasterous flood of 57,000 c.f.s.*3, only 24 hours later, at midnight April 26th.*4

The rapid runoff from this watershed is further emphasized in that the flow dropped back to 5,000 c.f.s. only five days from the initial rise through that value.

A total storm runoff of three and three-quarter inches from a little over four inches of rain, averaged over the watershed, clearly indicates the previously saturated conditions of the basin.

<u>(ii) April 1947</u>

"The April flood of 1947 was considered at the time to equal or surpass that of 1937. However, it was only below London that the water rose to nearly the same height".*5

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*2 John Patterson, the precipitation of the Grand & Thames River Basins, The Engineering Journal, The Engineering Institute of Canada, Montreal - Vol XXI, No. 2,

*3 B.P. Sangal, Unpublished Report "Flood Control on the Thames River", Conservation Authorities Branch, Ontario Department of Energy and Resources Management, 1966.

*4 Norman Marr, Surface Runoff in the Thames and Grand River Basins in Ontario, The Engineering Journal, The Engineering Institute of Canada, Montreal - Vol XXI No. 2. February 1938.

*5 Upper Thames Valley Conservation Report - 1952, ibid.

The flood of early April 1947 occurred at the end of a very snowy winter and though data as to the amount of snow on the ground on this watershed are very sketchy for 1947, considerable insight may be obtained from related meteorological records.

It should first be pointed out that the snowbelt area of Southern Ontario is centred on the plateau, north of the Thames watershed, but its effect extends southward into the Thames basin. In all winters with normal or above normal snow, one finds amounts increasing steadily as one proceeds northward from London.

At the end of February 1947, London reported six inches of snow on the ground while Stratford near the north end of the watershed reported 23 inches; further north, out of the watershed, depths reached four feet.

During the month of March, 30 inches of newly fallen snow occurred over the watershed. If we assume that the snow on the ground had a water content of 25 per cent and that of newly fallen snow 10 percent then we arrive at a rough estimate of six inches as the water content of the snow on the watershed toward the end of March.

Mild temperatures between 45° and 55° on March 23rd and 24th along with three-quarters of an inch of rain caused the initial breakup of the river on the 25th. Temperatures however dropped below freezing for the remainder of March bringing an end to the melting and a sharp decrease in flow from the moderate peak on the 25th. About two inches of runoff occurred during the last half of March.

At the beginning of April there was still a considerable amount of snow on the watershed in gullies, ditches and woodlots, particularly in the northern section.

From the chart showing the flood data (figure 3) it can be seen that daytime temperatures rose into the forties on the first while on the second about an inch of rain occurred over the watershed. This combination of conditions brought a marked increase to the rate of runoff.

At this time a major low pressure area was developing over the central plain states. As this storm centre moved northeastward, heavy rain and warm air moved into Southern Ontario.

The surface weather map on the morning of April 5th is seen in Figure 8. The rainfall of two and one-half inches in 24 hours at London is indicative of the amounts over the southern part of the watershed. Amounts decreased northward to about one and one-half inches. Temperatures on the 5th shot up to the sixties causing rapid melting of an already well-ripened snowpack.

This combination of excessive melt water and heavy rain generated a flood peak of over 42,000 c.f.s. on the morning of the 6th. The total runoff for the period of the 2nd to the 10th was four and one=third inches.

<u>(iii) March 1948</u>

"The flood of March 1948 lasted about 5 days and repeated many of the details of 1947. The height of the rise was nowhere so great as in the previous April and the Thames watershed suffered less than some other areas in Western Ontario. Nevertheless, the cost of the flood was probably equal to that of 1947".*6

The weather was cold throughout the first two weeks of March with temperatures remaining below freezing. Snowfall amounts were a little below normal with an estimated five to ten inches of snow on the ground at the middle of March for a water content of 2 to 3 inches. An influx of warm air developed over Southern Ontario on the 15th as a storm centre developed in the mid-western plain states and about one-half an inch of rain occurred over the watershed as the weather system moved through. Snowmelt and rain created a sharp rise in river flow on the 16th but this subsided as an influx of cold air brought freezing temperatures for the next two nights.

Another low pressure area developed over the southwestern states and moved rapidly northeastward bringing warm air with temperatures in the fifties to the Thames basin and between one and two inches of rain. The weather map for the morning of the 19th is shown in figure 9. The runoff again reacted quickly to the combination rain and snowmelt, as in 1947, with a peak flow of 40,000 c.f.s. occurring in the early morning of March 20th- figure 4.

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*6 Upper Thames Valley Conservation Report, 1952 - Ibid.

The occurrence of the flood peak between midnight and morning is a feature of this watershed, when snowmelt is a major contributor to runoff, and is directly related to the period of maximum temperatures in the afternoon of the previous day.*7 Another one-half inch of rain occurred over the watershed on the 21st with no marked effect on the flow pattern. The total runoff from rain and snowmelt for the period from March 15th to 25th was close to four and one-half inches.

(iv) March - April 1960

In January and early February 1960, there were frequent mild rainy periods with very little accumulation of snow. However, late in February, snow began to fall and by the end of the month the snow on the ground was much above normal. Cold weather was established by the beginning of March and continued until warming set in on the 27th of the month. The snow on the ground prior to the melt period ranged from 15 inches in the southern part of the watershed to 30 inches in the north with an average water content over the basin of 5 inches.*8

The predominant feature of the synoptic charts for March was the persistant meridional flow pattern aloft throughout the extended cold period and then the abrupt change to a zonal flow bringing mild weather. With this strong air-flow across the continent from west to east, minor low pressure areas developed at the surface and moved rapidly through Southwestern Ontario giving small amounts of rain as indicated on figure 5. The surface weather map for the morning of March 30th is shown in figure 10. The temperature into early April remained relatively mild with no influx of very warm air. Maximum temperatures, in general, ranged from the forties to the mid-fifties.

After four days of melting with temperatures finally climbing to the mid-fifties on the 30th, a sharp increase in the rate of flow developed, reaching a peak of near 28,000 on the 31st.

Freezing temperatures for the next two nights and cool daytime readings reduced the melting and caused a drop in the flow. A return to warm temperatures on April 2nd and

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*7 D.N. McMullen, Hydrometeorological Aspects of the 1960 Spring Breakup in Southwestern Ontario, Meteorological Branch, Department of Transport, Circular 3440, January, 1961

*8 D.N. McMullen, ibid

3rd completed the melting and created a peak flow similar to that at the end of March. The total runoff of over five and one-half inches was very high, occurring primarily within the nine day period from March 30th to April 7th.

(v) March 1963

The first three weeks of March 1963 were abnormally cold with only two or three days having temperatures much above freezing. A period of warm weather was established on the 23rd.

At the middle of March, the snow on the ground ranged from 15 inches in the southern part of the watershed to 30 inches in the north for an average water content for the whole basin of over four inches.

The marked warming was occasioned by the movement of a low pressure area from the central plain states northeastward across Southern Ontario. The surface weather map for the morning of March 25th is shown in figure 11. This warm air with maximum temperatures in the low sixties on the 24th and 25th caused considerable melting. The streamflow increased sharply to a peak of 29,000 c.f.s. (estimated uncontrolled) by the early morning of the 26th (figure 6). Rainfall amounts on the 25th were quite variable ranging from one-quarter to three-quarters of an inch.

With temperatures remaining above freezing but with maximum temperatures down some ten degrees from the previous high readings, melting progressed steadily with the high flow in the river persisting for the next two days. With the completion of the snowmelt by the 28th, the uncontrolled flow showed a marked decrease.

The rainfall on the night of the 26th to 27th varied from one-half to three-quarters of an inch over the watershed but was not sufficient to cause a major increase in flow. The estimated uncontrolled peak is shown as 34,000 c.f.s. (figure 6) on the 27th.

The total runoff for the seven day period from March 25th to 31st was 3.8 inches.

4. Conclusions

From an examination of these five extreme floods on the Thames River over the past thirty years, a number of significant features becomes apparent.

Floods may be caused by rainfall alone as in 1937, by a mixture of snowmelt and rain as in 1947 and 1948, and by snowmelt alone as in 1960 and 1963.

The dates of these floods cover the period from mid-March to the end of April. However, those in which snowmelt was a contributing factor occurred within the last half of March and the first part of April.

In those cases where heavy rain was a contributing factor to the flood, this was associated with a deep low pressure area which moved from the central or southern plain states northeastward across Southern Ontario.

The rapid generation of a flood on the Thames River as a consequence of heavy rain on an already saturated watershed is well shown by the flood of 1937. This condition, of a saturated watershed, is the usual one prevailing each year, for a varying period after the snowmelt runoff, and therefore presents a potential threat in the event of early spring rains.

When rain occurs during the snowmelt period, the runoff is most seriously aggravated if it occurs towards the end of the period after the snow has become well-ripened.

The presence of an excessive amount of snow on the ground is not in itself a guarantee of floods though high flows can generally be expected with these conditions. However, when there is a heavy snow cover, the meteorological conditions prevailing during the melt period are very critical.. A few degrees difference in temperature, or rainfall displaced a few hours can be sufficient to change the flow from one that can be contained within the channel to one that overflows the banks and causes considerable damage.

The 12 to 15 hour lag-time between the afternoon maximum temperature and the snowmelt peak next morning is particularly significant for flood protection work in that the onset of flooding will occur during the night when protective and emergency action is most difficult.

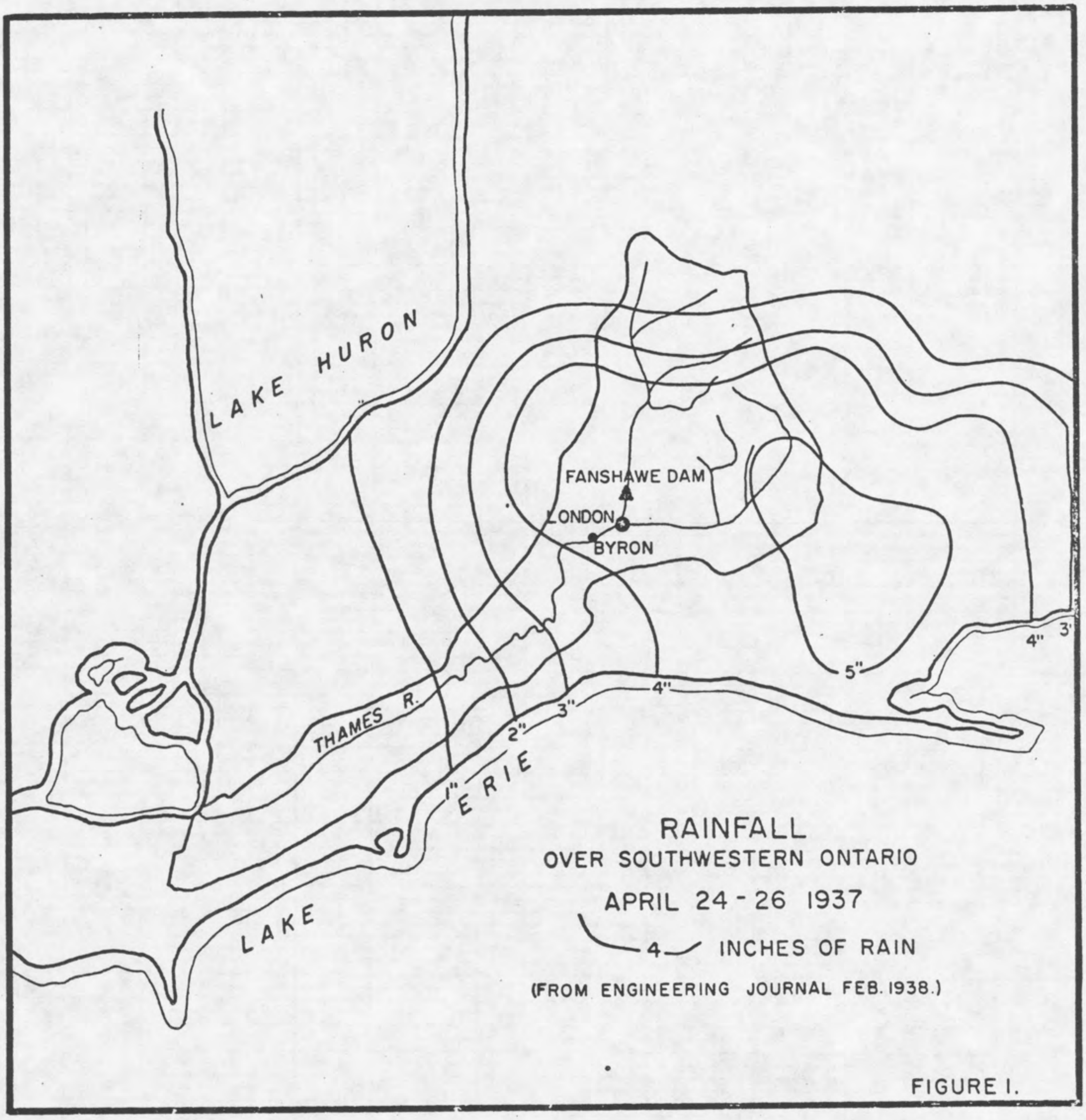

LAKE HURON
FANSHAWE DAM
LONDON
BYRON
THAMES R.
LAKE ERIE
1"
2"
3"
4"
5"
4"
3'
RAINFALL
OVER SOUTHWESTERN ONTARIO
APRIL 24 - 26 1937
4 INCHES OF RAIN
(FROM ENGINEERING JOURNAL FEB. 1938.)

FIGURE I.

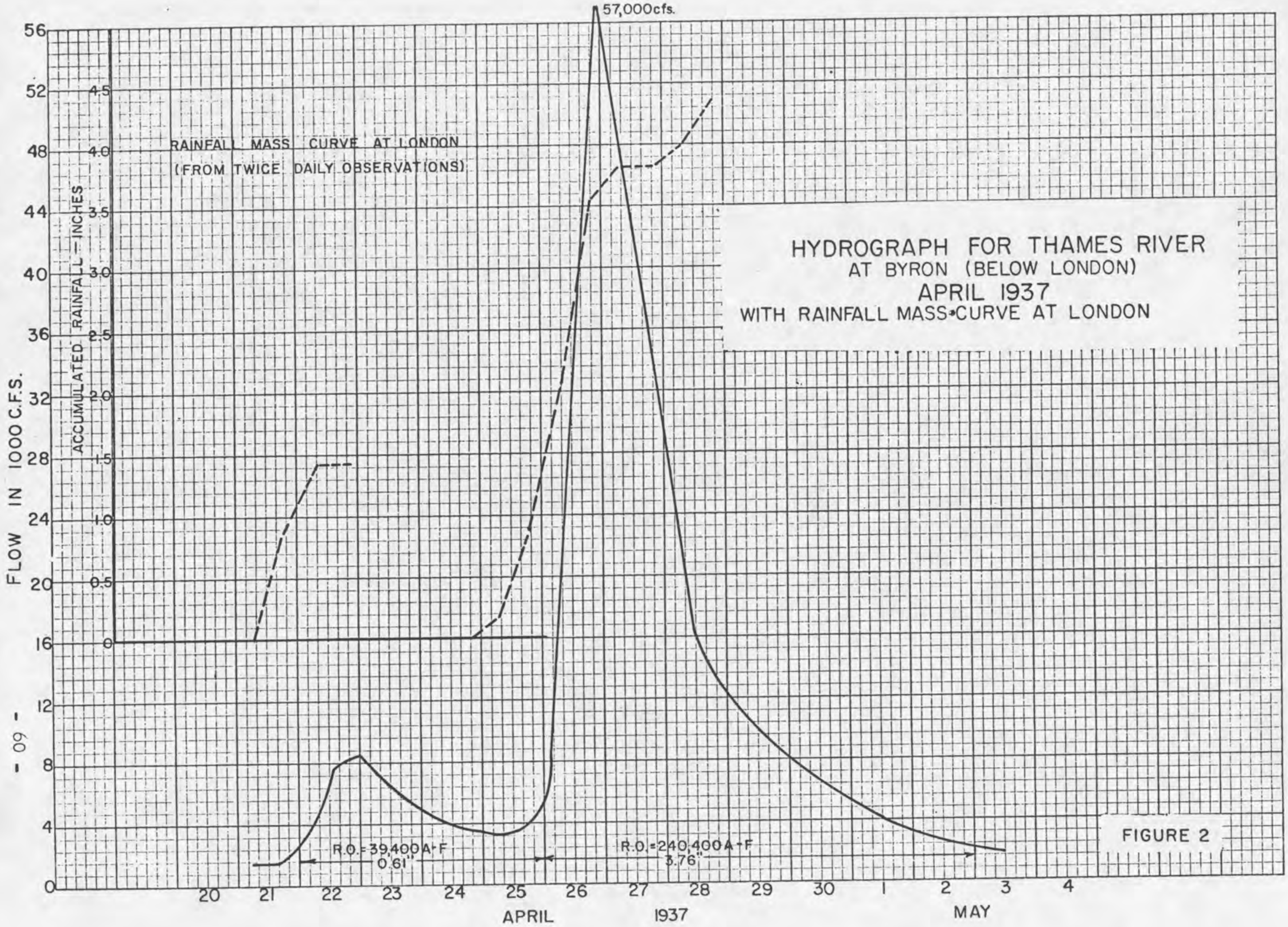
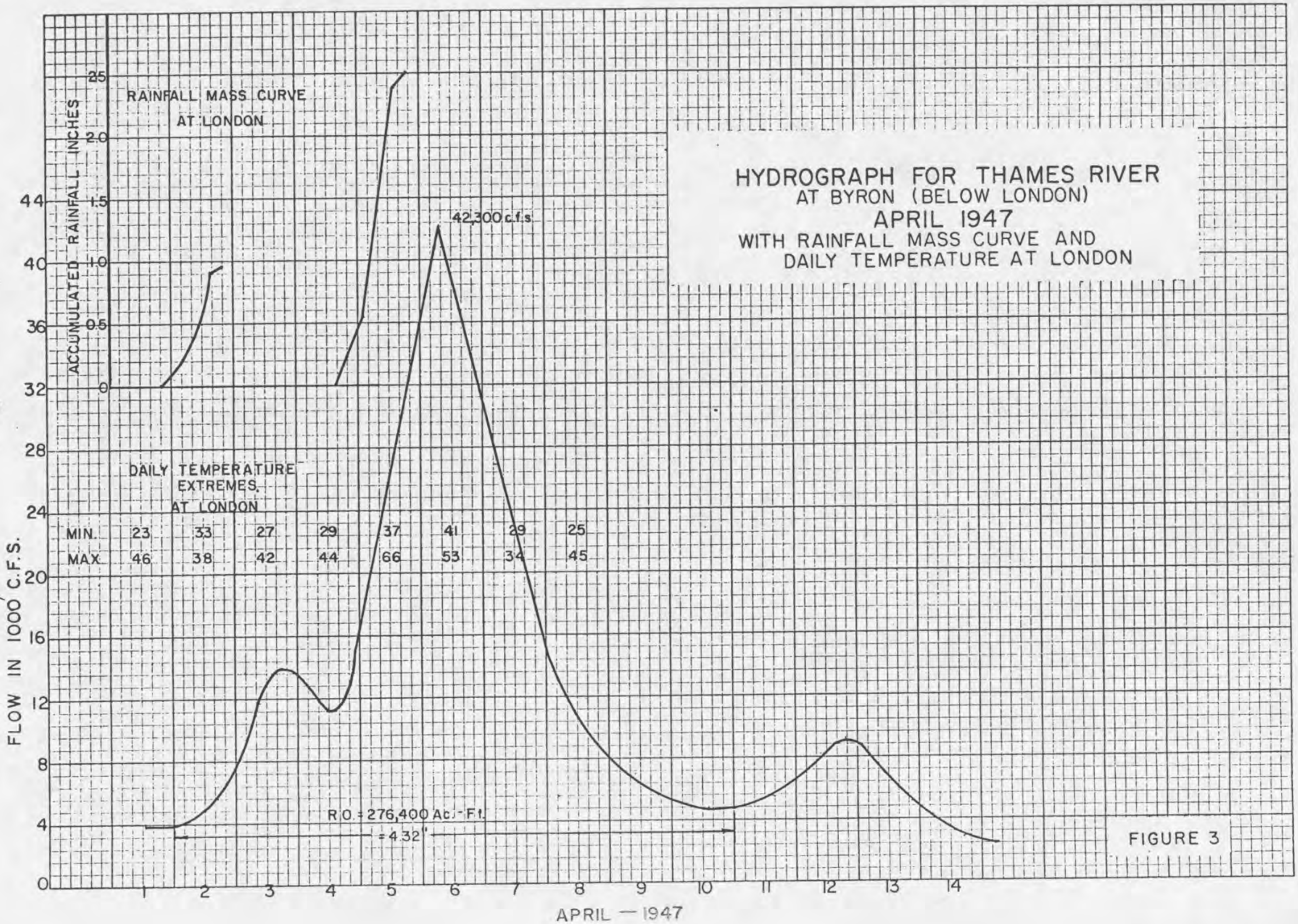

57,000cfs.
RAINFALL MASS CURVE AT LONDON
(FROM TWICE DAILY OBSERVATIONS)
HYDROGRAPH FOR THAMES RIVER
AT BYRON (BELOW LONDON)
APRIL 1937
WITH RAINFALL MASS-CURVE AT LONDON
FLOW IN 1000 C.F.S.
ACCUMULATED RAINFALL - INCHES
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
R.O.=39,400A-F
0.61"
R.O.=240,400A-F
3.76"
20 21 22 23 24 25 26 27 28 29 30 1 2 3 4
APRIL
1937
MAY

FIGURE 2



HYDROGRAPH FOR THAMES RIVER
AT BYRON (BELOW LONDON)
APRIL 1947
WITH RAINFALL MASS CURVE AND
DAILY TEMPERATURE AT LONDON
RAINFALL MASS CURVE
AT LONDON
ACCUMULATED RAINFALL INCHES
42,300 c.f.s.
DAILY TEMPERATURE
EXTREMES.
AT LONDON
MIN. 23 33 27 29 37 41 29 25
MAX. 46 38 42 44 66 53 34 45
R.O. = 276,400 Ac.-Ft.
= 4.32"
FLOW IN 1000 C.F.S.
APRIL — 1947

FIGURE 3

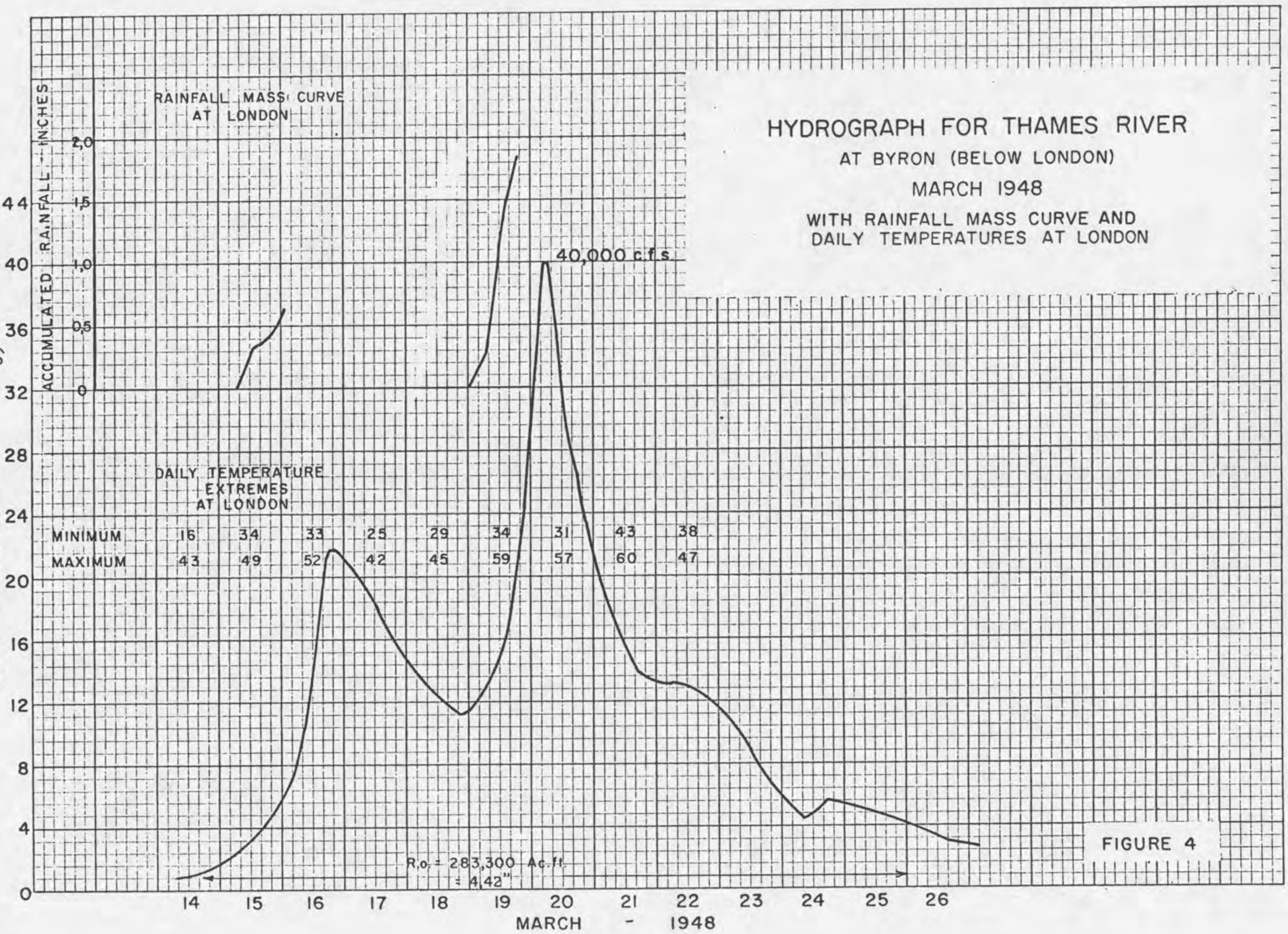

HYDROGRAPH FOR THAMES RIVER
AT BYRON (BELOW LONDON)
MARCH 1948
WITH RAINFALL MASS CURVE AND
DAILY TEMPERATURES AT LONDON
RAINFALL MASS CURVE
AT LONDON
ACCUMULATED RAINFALL - INCHES
2.0
1.5
1.0
0.5
0
40,000 c.f.s.
DAILY TEMPERATURE
EXTREMES
AT LONDON
MINIMUM 16 34 33 25 29 34 31 43 38
MAXIMUM 43 49 52 42 45 59 57 60 47
FLOW IN 1000 c.f.s.
44
40
36
32
28
24
20
16
12
8
4
0
R.o. = 283,300 Ac.ft.
= 4.42"
14 15 16 17 18 19 20 21 22 23 24 25 26
MARCH - 1948

FIGURE 4

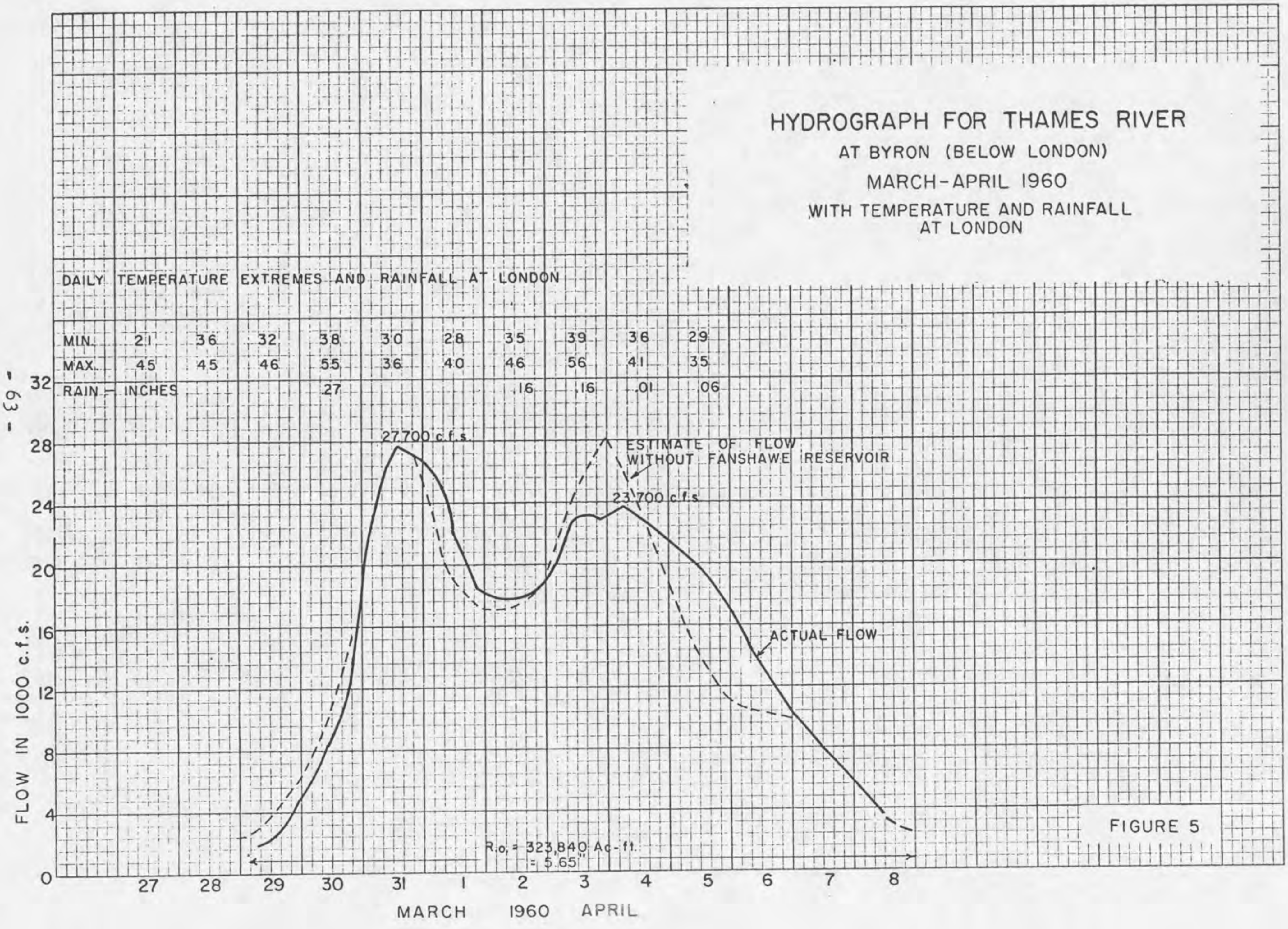
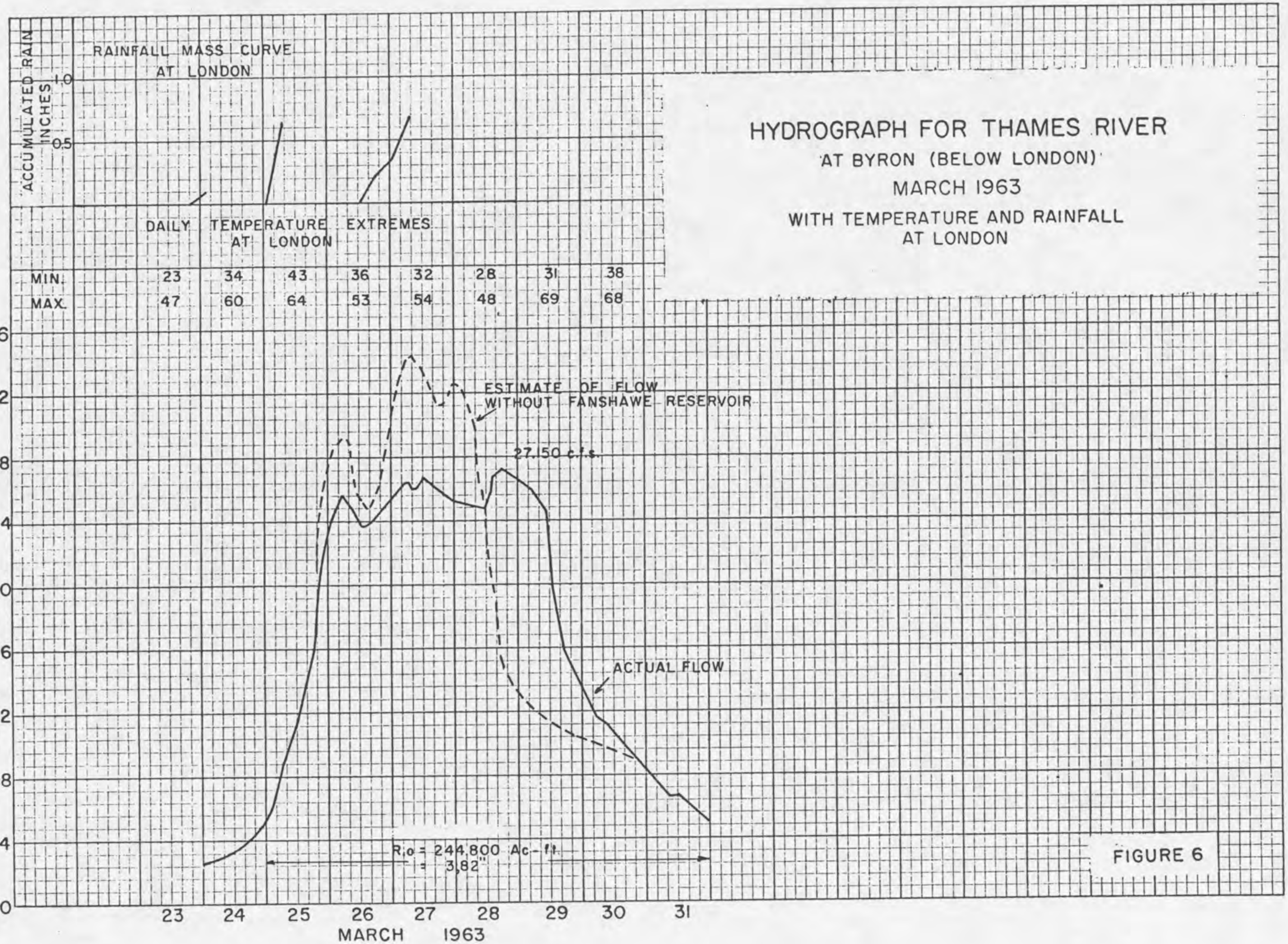
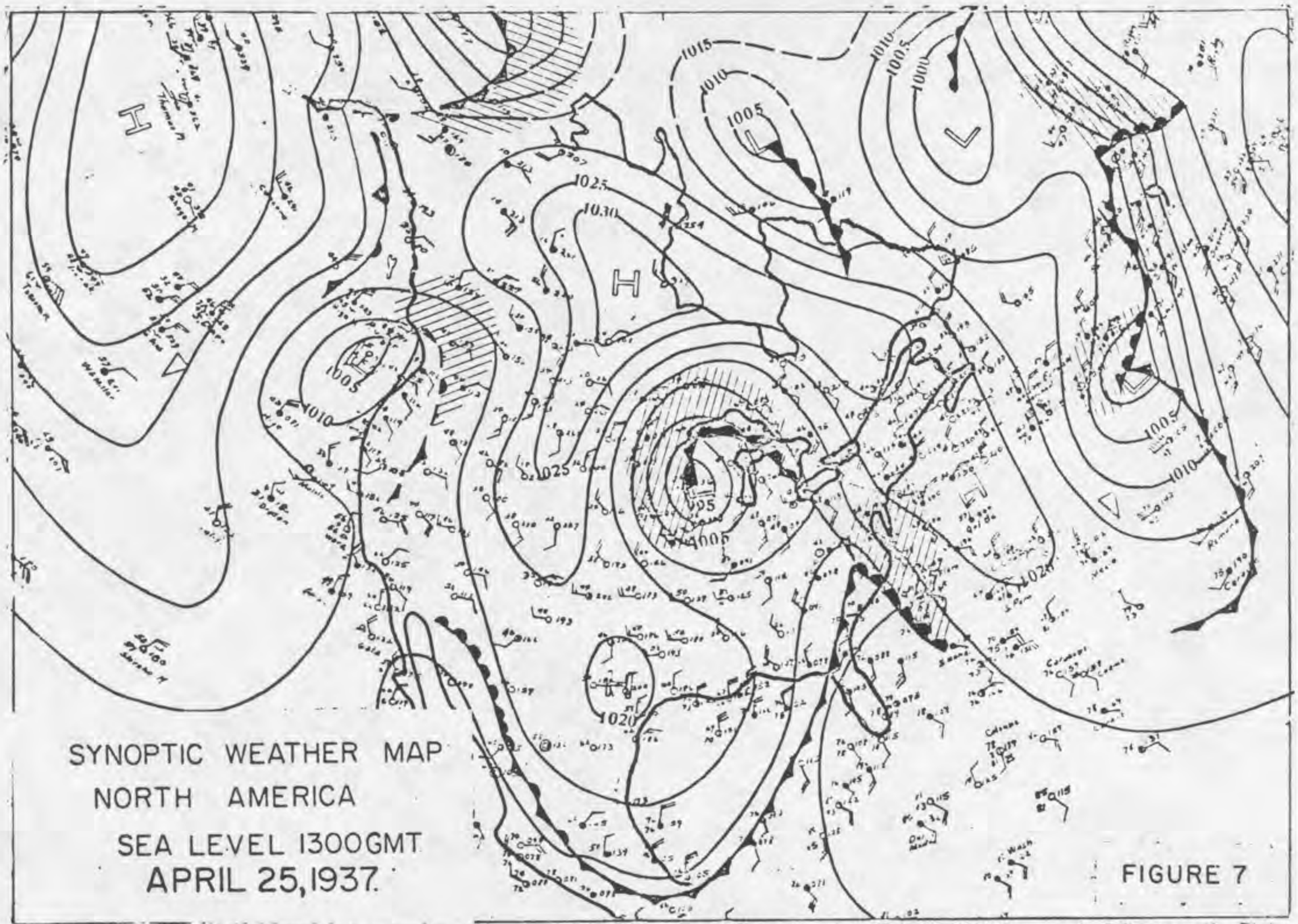

HYDROGRAPH FOR THAMES RIVER
AT BYRON (BELOW LONDON)
MARCH-APRIL 1960
WITH TEMPERATURE AND RAINFALL
AT LONDON
DAILY TEMPERATURE EXTREMES AND RAINFALL AT LONDON
MIN. 21 36 32 38 30 28 35 39 36 29
MAX. 45 45 46 55 36 40 46 56 41 35
RAIN – INCHES .27 .16 .16 .01 .06
27700 c.f.s.
ESTIMATE OF FLOW
WITHOUT FANSHAWE RESERVOIR
23700 c.f.s.
ACTUAL FLOW
R.o. = 323,840 Ac-ft.
= 5.65"
FLOW IN 1000 c.f.s.
0
4
8
12
16
20
24
28
32
27
28
29
30
31
1
2
3
4
5
6
7
8
MARCH 1960 APRIL

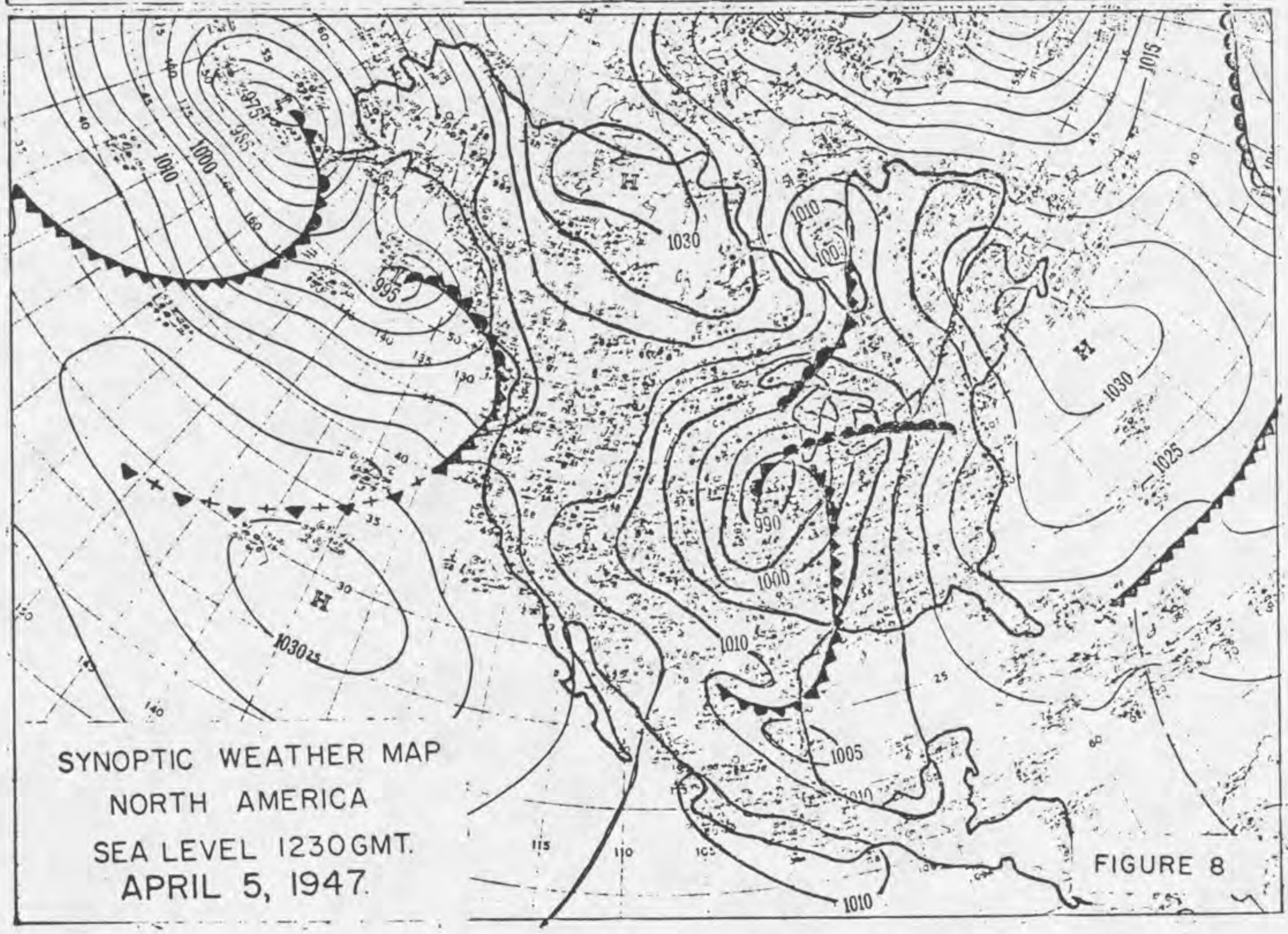
FIGURE 5


HYDROGRAPH FOR THAMES RIVER
AT BYRON (BELOW LONDON)
MARCH 1963
WITH TEMPERATURE AND RAINFALL
AT LONDON
RAINFALL MASS CURVE
AT LONDON
ACCUMULATED RAIN INCHES
1.0
0.5
DAILY TEMPERATURE EXTREMES
AT LONDON
MIN. 23 34 43 36 32 28 31 38
MAX. 47 60 64 53 54 48 69 68
ESTIMATE OF FLOW
WITHOUT FANSHAWE RESERVOIR
27,150 c.f.s.
ACTUAL FLOW
R.o = 244,800 Ac-ft.
= 3.82"
FLOW IN 1000 c.f.s.
0
4
8
12
16
20
24
28
32
36
23
24
25
26
27
28
29
30
31
MARCH 1963
FIGURE 6



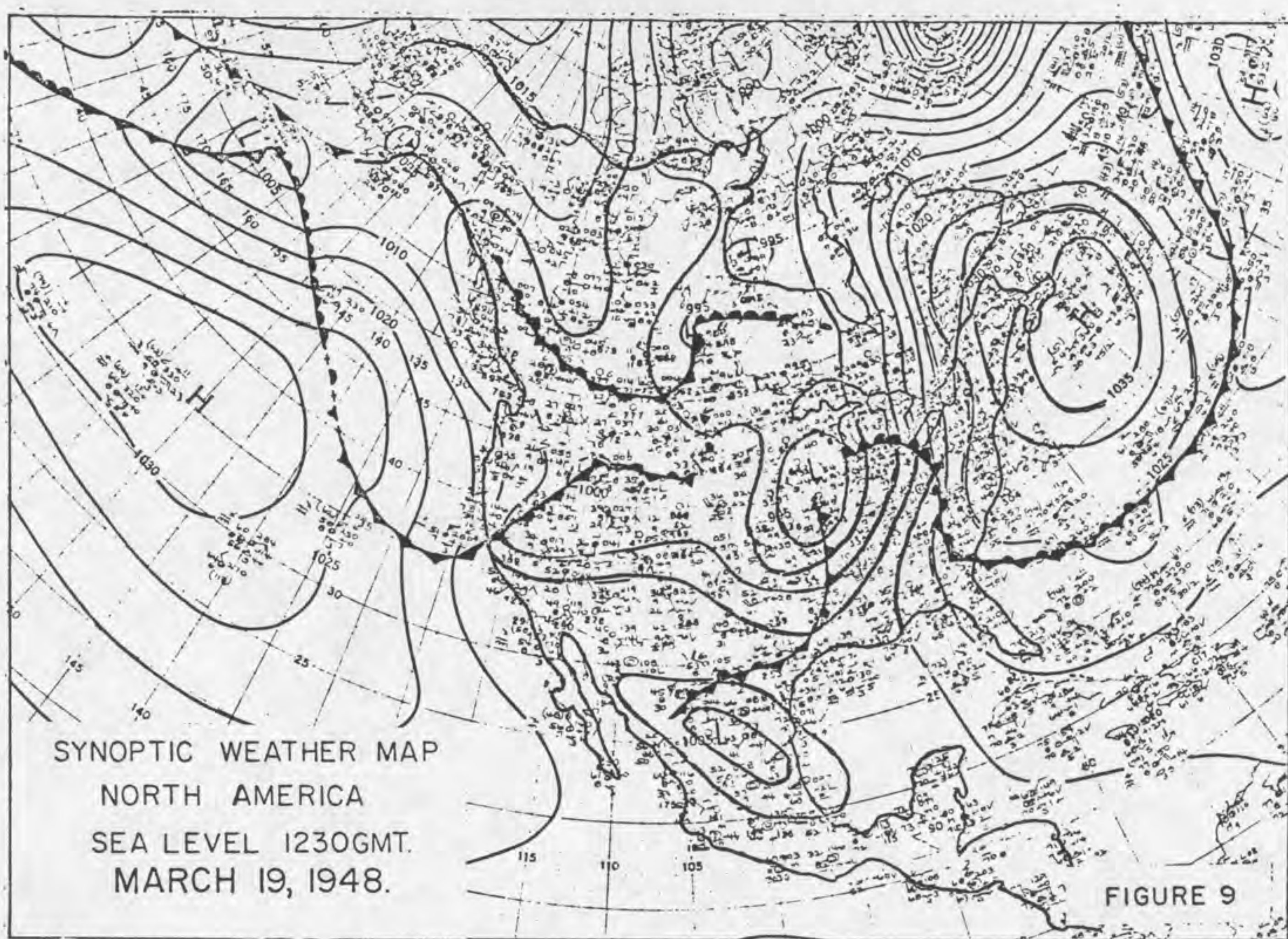
SYNOPTIC WEATHER MAP
NORTH AMERICA
SEA LEVEL 1300 GMT
APRIL 25, 1937.

FIGURE 7



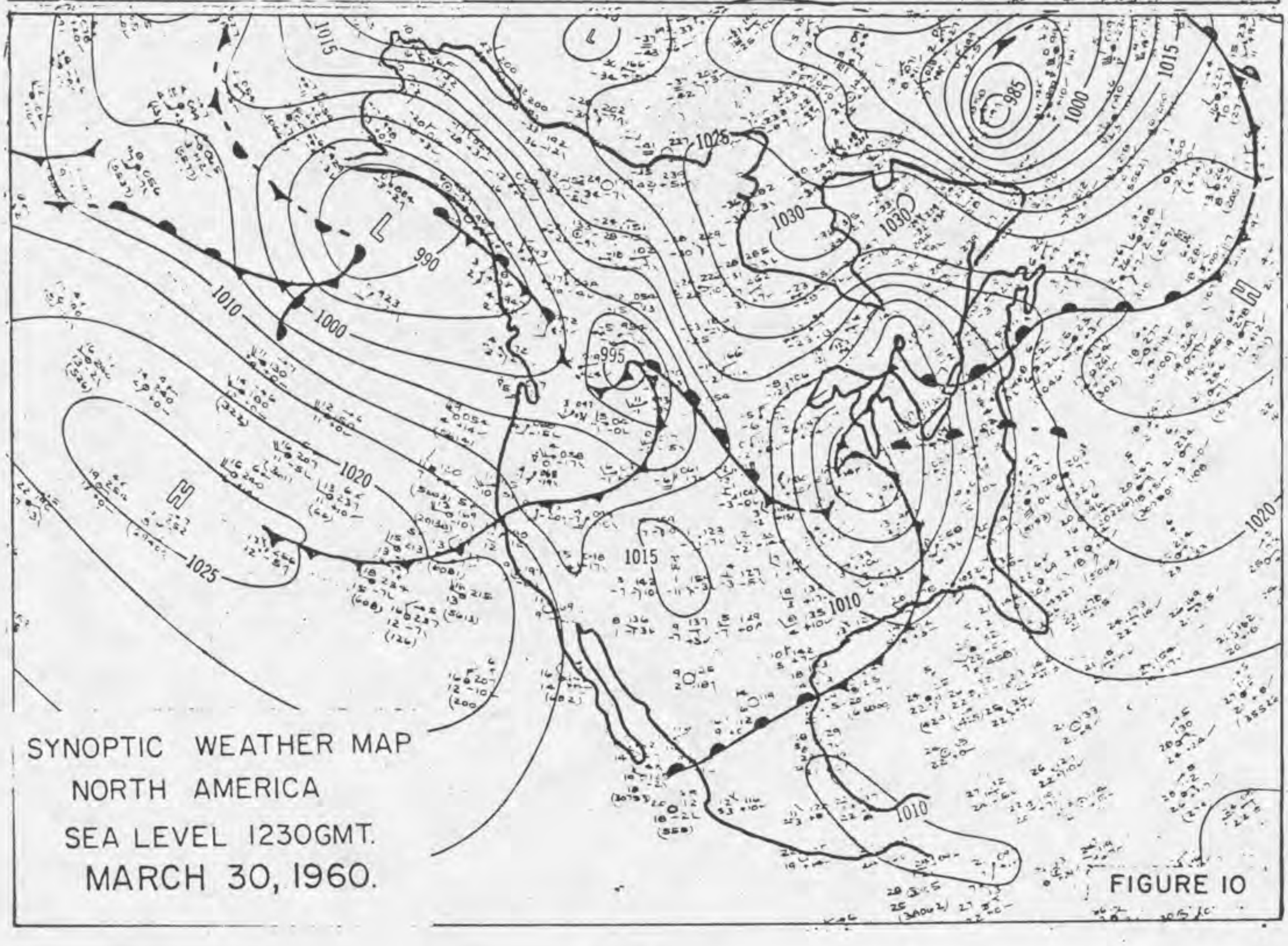
SYNOPTIC WEATHER MAP
NORTH AMERICA
SEA LEVEL 1230 GMT.
APRIL 5, 1947.

FIGURE 8



SYNOPTIC WEATHER MAP
NORTH AMERICA
SEA LEVEL 1230GMT.
MARCH 19, 1948.

FIGURE 9



SYNOPTIC WEATHER MAP
NORTH AMERICA
SEA LEVEL 1230GMT.
MARCH 30, 1960.

FIGURE 10

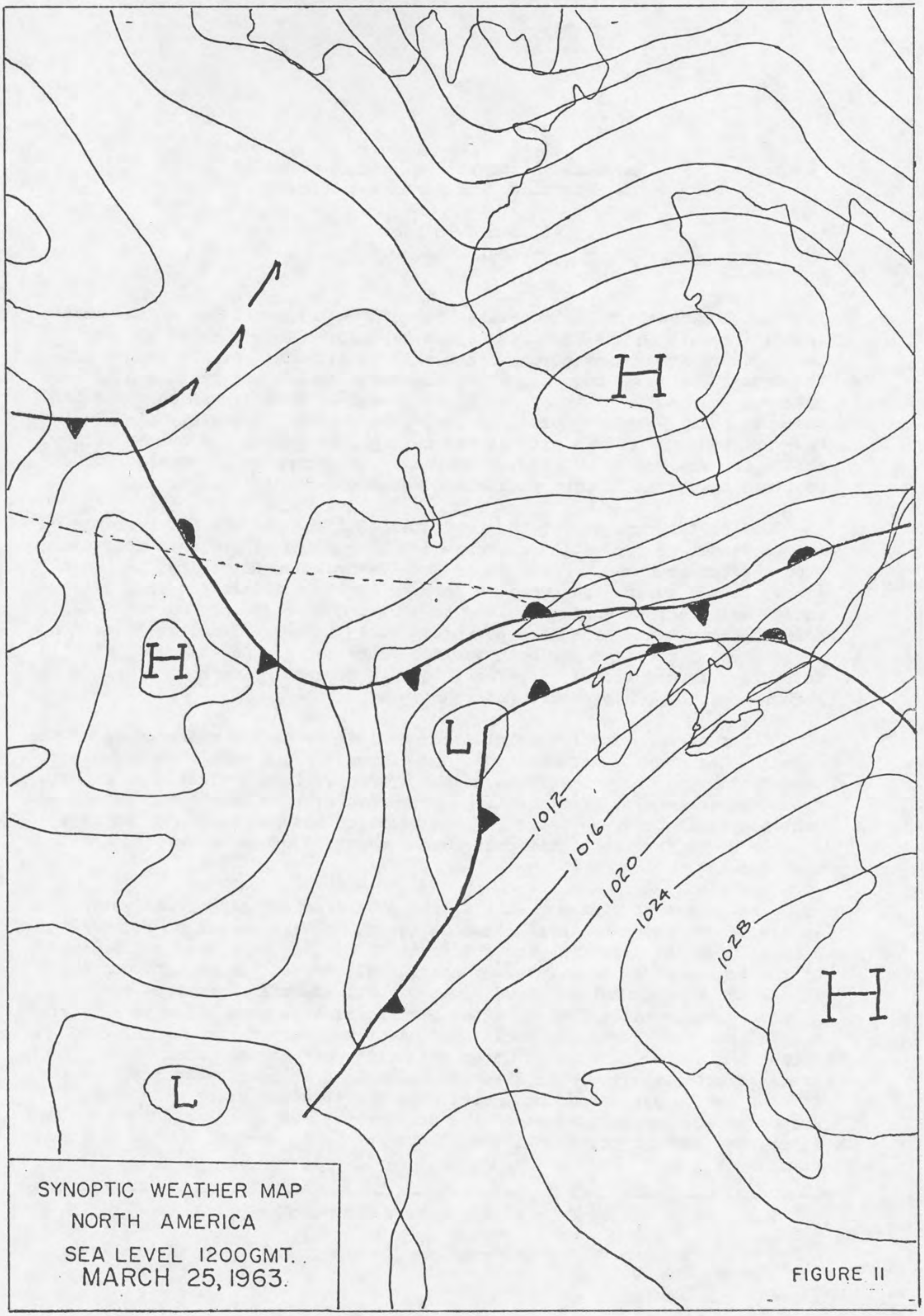

H
H
L
L
H
1012
1016
1020
1024
1028
SYNOPTIC WEATHER MAP
NORTH AMERICA
SEA LEVEL 1200GMT.
MARCH 25, 1963.

FIGURE II