Alston F. Mugnier

HYDROLOGY REPORT
AS RELATED TO
SPILLWAY REQUIREMENTS
FOR
CLAREMONT DAM

U. S. Engineer Office,
Providence, R. I.
October 23, 1940

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

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HYDROLOGY REPORT FOR CLAREMONT DAM

OCTOBER 1940

Introduction

1. Authority. - This report is submitted in compliance with the provisions of Engineer Bulletin R. & H. No. 9, 1938, subject: Spillway Capacities, paragraph 19, which directs that:

> "a hydrology report will be submitted to this office as the first step in the final design of a project".

2. Scope. - This report discusses the procedure used and the results obtained in the studies for the determination of spillway requirements for Claremont Dam.

3. Location. - The proposed Claremont Dam will be in New Hampshire on the Sugar River, a tributary of the Connecticut River. The dam site is 7.1 miles above the junction of the Sugar River with the Connecticut River, and one mile southeast of Claremont, N. H. The reservoir will extend 4-1/2 miles up the Sugar River, and will be in the towns of Claremont and Newport, in Sullivan County, New Hampshire. The general location of the dam site is shown on Plate No. 1.

4. Watershed. - The watershed above the Claremont Dam site is generally hilly with a few sharp peaks. The general topography of the area, as shown on Plate No. 2, (taken from the Cardigan, Claremont, Lovewell Mountain, Mascoma, Mount Kearsarge, and Sunapee, N. H. topographic maps of the U. S. Geological Survey) indicates extensive swamp areas, lakes, and regions in the upper part of the watershed where the valley floor is broad and flat. There is therefore considerable natural

valley storage along the stream channels. Sunapee Lake, with a water surface area of 6.6 square miles, has a controlled capacity equal to 14.3 inches of run-off from its drainage area of 46 square miles.

5. Reservoir. - The dam will form a reservoir of 78,400 acre-feet capacity at the spillway crest, which is equivalent to 6.0 inches of run-off from the drainage area of 245 square miles. The area and capacity curves are shown on Plate No. 3. The reservoir capacity will be utilized for flood control storage only.

Hydrology

6. Rainfall records. - Within a radius of 30 miles of the dam site there are 30 rainfall stations with periods of record ranging from 2 to 104 years. Their locations are shown on Plate No. 4, and their periods of record on Plate No. 5. Pertinent general precipitation data are:

Mean annual rainfall	- 37.0 inches	(including snow)
Maximum annual rainfall	- 48.1 "	(" ")
Minimum annual rainfall	- 27.3 "	(" ")
Mean annual snowfall	- 74.2 "	

Approximate water equivalent of mean annual snowfall - 7.4 inches

Mean Monthly Precipitation

January	2.94 in.	May	2.91 in.	September	3.56 in.
February	2.27 in.	June	3.46 in.	October	2.84 in.
March	2.94 in.	July	4.01 in.	November	2.94 in.
April	3.18 in.	August	3.32 in.	December	2.67 in.

Maximum storm of record in this general region:

Date - September 17-21, 1938

Duration - 98 hours

Maximum average depth of rainfall on 245 square miles - 15.5 inches.

The area-depth graphs and locations of the storm centers of the maximum summer and winter storms of record are shown on Plates No. 6 and No. 7, respectively.

7. Run-off records. - Run-off records have been collected by the U. S. Geological Survey at West Claremont, with a drainage area of 269 square miles, on the Sugar River, since October 1928. Twelve other stream gaging stations are located in the same general vicinity, as shown on Plate No. 4. Periods of record of these stations are shown on Plate No. 8. Pertinent run-off data at the dam site, based on the records of the Sugar River at West Claremont, N. H., are:

Mean annual run-off - 20.92 inches
Maximum annual run-off - 25.98 "
Minimum annual run-off - 12.57 "

Mean Monthly Run-off and Percent Run-off

January	1.46	inches	42.4%	July	0.88	inches	22.8%
February	0.96	"	44.8%	August	0.55	"	14.5%
March	2.90	"	88.8%	September	0.88	"	23.1%
April	7.05	"	192.1%	October	0.56	"	21.2%
May	2.31	"	78.8%	November	1.05	"	51.7%
June	1.19	"	33.0%	December	1.05	"	38.7%

Note: Percent run-off based on mean monthly precipitation given in preceding paragraph and includes the effect of storing and melting of snow.

Through field investigation and research, historical knowledge of several of the most severe floods on the Sugar River within the past 125 years was obtained. They are known to have occurred in February 1824, February 1839, January 1841, April 1843, March 1859, April 1869, October 1869, April 1870, March 1913, November 1927, March 1936, and September 1938. Prior to October 1928, the exact order of magnitude is not known. Since then, the March 1936 flood had the greatest peak discharge at the dam site. Based on the gage records

for the Sugar River at West Claremont, the March 1936 peak discharge at the Claremont Dam site was estimated to be 12,700 cubic feet per second, and the September 1938 peak discharge was estimated to be 11,900 c.f.s. Envelope curves of summer and winter peak discharges of record are shown on Plates No. 9 and No. 10, respectively.

8. Effect of existing storage on run-off. - The numerous natural lakes and ponds in the watershed have a large modifying effect on flood run-off. The largest of these, Sunapee Lake, provides virtually complete control of the run-off from its drainage area of 46 square miles. The water rights at Sunapee Lake are owned and operated by the Sunapee Dam Corporation, a syndicate consisting of 17 mills located downstream from the lake. It includes the Public Service Company of New Hampshire, which operates hydro-electric developments along the river. The Sunapee Dam Corporation is required by State law to maintain the lake level between 8.5 and 11.5 feet on the lake gage from May 15 to September 15 of each year. This requirement is due to the recreational development that borders the entire lake. The lake level is not allowed to exceed 11.5 feet on the gage except in times of flood when the outlet capacity is not sufficient to maintain this level. The lake has a surcharge storage equivalent to 1.72 inches of run-off from its entire drainage area for each foot of surcharge, and a very limited discharge capacity provided entirely by three sluiceways 4.66 feet by 11.0 feet. Two of these sluiceways are normally closed by stop-logs, and the third has a gate. The sluiceways are open only during extremely high floods, and the discharge even then is limited by sur-

charge storage and by a downstream dam, the crest of which is only three feet below the maximum operating level of the lake. The lowest gage height ever experienced on the lake is 6.25 feet, and the maximum is 13.10 feet, which occurred during the March 1936 flood. Area and capacity curves for the range of controlled storage, and the maximum possible outlet rating, all based on the datum of a staff gage at the outlet, are shown on Plate No. 17. The existing outlet structure is of modern concrete construction, designed and built under the supervision of The J. G. White Engineering Corporation, Consulting Engineers. The structure is founded on ledge rock and is capable of withstanding, by overtopping, the maximum discharge that would result from the worst possible storm occurring over the contributing watershed, with all the gates closed.

9. Unit hydrograph derived from floods of record. - Unit hydrographs have been derived from floods of record at the U. S. Geological Survey gaging station at West Claremont, New Hampshire. This gaging station, established in October 1928, is located 4-1/2 miles downstream from the dam site and has a gross drainage area of 269 square miles. Data pertinent to the derivation of unit hydrographs are shown on Plates No. 11 to No. 15, inclusive, for the floods of November 1932, March 11-12, 1936, March 18-19, 1936, May 1937, and September 1938. As will be noted, the outflow from Sunapee Lake routed to the gaging station has been eliminated from the gross drainage area, and the unit hydrographs have been computed for the net drainage area of 223 square miles. The outflow from Sunapee Lake, though almost negligible, was reconstituted from

staff gage readings of the lake level during the floods used to derive unit hydrographs. A comparison of the 6-hour unit hydrographs derived and the adopted unit hydrograph (that derived from the flood of September 1938) for the net drainage area at West Claremont is shown on Plate No. 16.

10. Unit hydrographs for use in reconstituting great floods at Claremont Dam. - Because of the controlling effect of Sunapee Lake, reconstitution of great floods at Claremont Dam site should be effected by adding the routing outflow of the flood at Sunapee Lake to the flood determined for the residual drainage area of 199 square miles. Consequently, two unit hydrographs have been adopted, one for each of these areas.

a. Unit hydrograph for Sunapee Lake. - A six-hour unit hydrograph for Sunapee Lake has been determined from empirical topographic relations for the Connecticut River Watershed ("The Unit Hydrograph and Flood Routing", by G. T. McCarthy). This unit hydrograph has been adopted for use in reconstituting inflow floods at Sunapee Lake, and is evaluated in Table I. It was not practicable to derive a unit hydrograph from stage records at the lake because the large surface area of the lake in relation to its drainage area results in a lack of sensitivity of the gage. Conversely, the shape of the unit hydrograph adopted is unimportant, because of the large storage available over the surface of the lake.

b. Unit hydrograph for net drainage area. - The unit hydrograph adopted for the net drainage area of 199 square miles, after excluding the Sunapee Lake drainage area, was determined by reducing

TABLE I - ADOPTED AND DISTORTED 6-HOUR UNIT HYDROGRAPH VALUES

Time in hours	Unit hydrograph values in cubic feet per second							
	Net drainage area - 199 sq. mi.				Sunapee Lake drainage area - 46 sq. mi.			
	Adopted	Increase of peak discharge			Adopted	Increase of peak discharge		
		50%	100%	200%		50%	100%	200%
0	0	0	0	0	0	0	0	0
1-1/2	130	130	130	130	250	400	400	700
3	350	350	350	350	580	920	940	1,700
4-1/2	560	560	600	600	900	1,550	1,800	3,250
6	780	800	1,100	1,100	1,280	2,130	2,700	4,850
7-1/2	1,070	1,150	1,800	1,800	1,520	2,430	3,200	2,200
9	1,410	1,750	2,750	4,000	1,620	2,050	2,000	1,200
10-1/2	1,890	2,500	3,900	7,800	1,530	1,250	1,230	800
12	2,490	3,350	5,250	14,040	1,380	1,000	850	710
13-1/2	3,250	4,500	7,200	11,000	1,170	820	700	590
15	4,180	6,200	9,360	8,000	940	700	590	510
16-1/2	4,670	7,020	7,100	5,750	790	610	510	430
18	4,680	6,500	5,400	4,100	670	540	450	380
19-1/2	4,320	5,650	4,200	2,900	600	490	390	340
21	3,950	4,900	3,250	2,250	550	450	360	310
22-1/2	3,620	4,200	2,650	1,800	510	410	320	280
24	3,340	3,250	2,240	1,520	470	370	300	250
25-1/2	3,070	2,630	1,880	1,240	440	340	270	230
27	2,840	2,220	1,680	1,120	420	300	240	210
28-1/2	2,600	1,950	1,550	1,020	400	270	220	190
30	2,390	1,700	1,360	920	370	250	200	170
31-1/2	2,180	1,550	1,240	850	350	240	180	160
33	2,020	1,400	1,160	780	330	220	170	150
34-1/2	1,860	1,280	1,090	720	310	200	160	140
36	1,730	1,180	1,040	660	290	190	150	130
39	1,490	1,040	920	610	250	160	130	110
42	1,310	900	830	570	210	140	110	90
45	1,160	810	760	500	170	120	100	70
48	1,040	720	680	450	140	90	80	60
51	940	640	620	400	110	60	50	40
54	860	550	550	360	70	40	30	30
57	780	490	490	310	40	20	20	20
60	710	430	430	260	0	0	0	0
66	570	340	340	220				
72	450	250	250	180				
78	330	200	200	140				
84	230	160	160	110				
90	160	130	130	80				
96	110	100	100	60				
102	70	70	70	50				
108	40	40	40	40				
114	10	10	10	10				
120	0	0	0	0				

the adopted unit hydrograph for the net drainage area at the West Claremont gaging station by the drainage area ratio (199/223). This unit hydrograph is also evaluated in Table I.

11. Forecast worst storms. - The forecast worst storms, with and without the condition of maximum snow cover, have been estimated for an area including the Claremont drainage basin by the U. S. Weather Bureau in "A Report on the Maximum Possible Precipitation over the Ompompanoosuc Basin above Union Village, Vermont".

a. Without snow cover. - The maximum possible rainfall in 48 hours, as given in this report, is 16.6 inches for a drainage area of 245 square miles, and 16.9 inches for a drainage area of 199 square miles, with intensity distributions in 6-hour periods as shown in the following table:

(Table II on the following page)

TABLE II - FORECAST WORST STORM WITHOUT SNOW

6-hour periods	Net D. A. - 199 sq. mi. Precipitation (in.)	Net D. A. - 199 sq. mi. Precip. minus infiltration*, or run-off (in.)	Net D. A. - 199 sq. mi. Percent run-off	Sunapee Lake D. A. - 46 sq. mi. Precipitation (in.)	Sunapee Lake D. A. - 46 sq. mi. Precip. minus infiltration*, or run-off (in.)	Sunapee Lake D. A. - 46 sq. mi. Percent run-off	Total D. A. - 245 sq. mi. Precipitation (in.)	Total D. A. - 245 sq. mi. Precip. minus infiltration*, or run-off (in.)	Total D. A. - 245 sq. mi. Percent run-off
1	0.10	.00	0	0.10	.00	0	0.10	.00	0
2	0.25	.00	0	0.25	.00	0	0.25	.00	0
3	2.00	1.70	85	2.00	1.70	85	2.00	1.70	85
4	9.10	8.80	97	7.50	7.20	96	8.80	8.50	97
5	4.00	3.70	92	4.00	3.70	92	4.00	3.70	92
6	1.10	0.80	73	1.10	0.80	73	1.10	0.80	73
7	0.25	.00	0	0.25	.00	0	0.25	.00	0
8	0.10	.00	0	0.10	.00	0	0.10	.00	0
Totals	16.90	15.00	89	15.30	13.40	88	16.60	14.70	89

* Infiltration estimated at 0.05 inch per hour

For determing run-off at the Claremont Dam site, the worse conditions of rainfall occur from the forecast worst storm of 16.9 inches in 48 hours over the net drainage area of 199 square miles (excluding Sunapee Lake and hereinafter referred to only as the net drainage area), and a synchronous storm over the Sunapee Lake drainage area of 46 square miles such that the total rainfall is equal to the forecast worst storm of 16.6 inches in 48 hours for the gross drainage area of 245 square miles. The resulting forecast worst storm for the Sunapee Lake drainage area is also shown in Table II. The intensity distributions are also shown on Plate No. 18. For means of comparison the curves of maximum rainfall intensities as determined by David L. Yarnell in the U. S. Department of Agriculture Miscellaneous Publication No. 204, for a frequency of 100 years, are shown on this plate. A curve of maximum intensities for a frequency of 100 years for Boston, Massachusetts, as given by Charles W. Sherman in his paper, "Frequency and Intensity of Excessive Rainfall in Boston, Massachusetts," Transactions of the American Society of Civil Engineers, Volume 95, 1931, is shown also. This latter curve is based on 50 years of recording gage records and is included because it is the result of a very thorough study of excellent records. Two points for the September 1938 storm, determined from non-recording gage records, are also shown on Plate No. 18. For shorter periods of time, the September 1938 storm intensity falls well below any of the curves shown. The area-depth relation of the forecast worst storm is shown on Plate No. 6.

b. With snow cover. - The forecast worst storm for the season during which maximum snow cover can occur, plus the yield from snow melt, is also given in the above-mentioned Weather Bureau report. The area-depth relation is shown on Plate No. 7, and its intensity distributions on Plate No. 18. For the drainage area of 245 square miles, the total depth in 48 hours is 23.5 inches. For determining run-off at the Claremont Dam site, an analysis of the worst conditions of rainfall plus the yield from snow melt similar to that explained in Paragraph 11 a above is given in Table III, following.

TABLE III - FORECAST WORST STORM WITH SNOW RELEASE

6-hour periods	Net D. A. 199 sq. mi. (inches)	Sunapee Lake D. A. 46 sq. mi. (inches)	Total D. A. 245 sq. mi. (inches)
1	2.0	1.6	1.8
2	2.4	1.9	2.3
3	3.3	2.6	3.1
4	5.9	4.6	5.7
5	3.9	3.1	3.8
6	2.6	2.1	2.6
7	2.2	1.7	2.2
8	2.0	1.5	1.8
Totals	24.3	19.1	23.3

Note: Values include precipitation plus snow release and represent run-off at 100 percent.

12. Computed spillway flood. - The natural computed spillway flood at the dam site was determined by adding the routed outflow of the flood at Sunapee Lake to the flood evaluated by applying the adopted unit hydrograph for the net drainage area of 199 square miles to the forecast worst storm for that area (see Tables I and II). The Sunapee Lake routed outflow results from the flood evaluated by the adopted unit hydrograph for the Sunapee Lake drainage area applied to the forecast worst storm for that area (see Tables I and II), and routed through the surcharge storage above the maximum operating stage of Sunapee Lake, and through the natural valley storage between Sunapee Lake and the dam site. The rainfall was distributed in 6-hour periods as defined in "A Report on the Maximum Possible Precipitation over the Ompompanoosuc Basin" and as shown in Table II and on Plate No. 22. An infiltration rate of 0.05 inch per hour was assumed. Studies show that this rate can be selected for a conservative minimum infiltration capacity. The resulting floods are shown on Plate No. 22. The resulting natural computed spillway flood at the dam site has a peak discharge of 58,600 cubic feet per second and a duration of 5-3/4 days.

13. Valley storage. - The natural valley storage within the reservoir area was evaluated by backwater studies. Manning's "n" coefficient was determined for the known profile and discharge (12,700 cubic feet per second) of the March 1936 flood. This coefficient was applied to discharges of 5,000, 30,000, 50,000, and 70,000 cubic feet per second to determine the profiles for these discharges. Valley storage was computed by the end area method for

each discharge. The resulting relation between flood discharge at the dam site and valley storage is shown on Plate No. 19. The curve, approximating a straight line, has been extended to a discharge of 150,000 cubic feet per second.

Spillway Hydraulics

14. Criteria for spillway design. - The spillway shall have sufficient capacity to pass the spillway design flood (see Paragraph 15 below) with no possibility of overtopping the dam even under the following adverse conditions:

a. The reservoir filled to spillway crest at the beginning of the spillway design flood.

b. The outlet gates closed.

c. The gates inoperative or the outlet passages blocked during the entire flood period.

d. The maximum possible wave height occurring at the instant of maximum spillway discharge.

15. Spillway design flood at the dam site. - The spillway design flood should be, for safety, somewhat more severe than the computed spillway flood. The forecast worst storm already includes a factor of safety, verified by increasing the supporting precipitation data on the basis of the maximum amount of precipitable water. Consequently, the only possibility of appreciable error lies in the manner in which the rainfall excess runs off, or the unit hydrograph. The adopted unit hydrographs have been used to determine the natural computed spillway flood at the dam site as explained in Paragraph 12.

A factor of safety of 50 percent, applied by distorting the basic unit hydrographs, would be reasonable and conservative. The natural spillway design flood at the dam site, for summer conditions of rainfall and run-off, shown on Plate No. 20, was computed by applying these more severe unit hydrographs to the forecast worst storm, assuming an infiltration rate of 0.05 inch per hour. These unit hydrographs have peak discharges 50 percent in excess of the adopted unit hydrographs, arbitrarily shortened lags, and the same base lengths, all as shown in Table I. The resulting spillway design flood has a peak discharge of 81,200 cubic feet per second, 332 cubic feet per second per square mile, 5190 times the square root of the gross drainage area, and 5740 times the square root of the net drainage area.

16. Spillway design flood under winter conditions. - A natural spillway design flood for the forecast worst storm with snow cover was similarly computed, using the unit hydrographs having peak discharges 50 percent in excess of the adopted unit hydrographs (see Table I) and the run-off given in Table III. The maximum spillway discharge resulting from this flood, as shown on Plate No. 20, is less than that for the spillway design flood computed from the forecast worst storm. Consequently, the spillway design flood determined from the forecast worst storm without snow (see Paragraph 15) governs the determination of the size of spillway.

17. Inflow spillway design flood. - The inflow spillway design flood was determined by eliminating the natural valley storage

in the reservoir area by the reverse flood-routing process. The resulting inflow spillway design flood, shown on Plate No. 20, has a peak discharge of 82,200 c.f.s., 336 c.f.s. per square mile, 5250 times the square root of the gross drainage area, and 5840 times the square root of the net drainage area.

18. Surcharge-discharge relation. - The inflow spillway design flood was routed through the surcharge storage for varying surcharges to determine the relation between maximum surcharge and required spillway discharge capacity. The results are shown graphically on Plate No. 21. A surcharge of 10 feet has been tentatively selected for the design studies now in progress. At this surcharge, the spillway discharge required is 77,100 cubic feet per second. The surcharge storage, for a surcharge of 10 feet, is 14,400 acre-feet, equivalent to 1.1 inches of run-off from the gross drainage area.

19. Spillway length. - The final type of spillway has not been selected pending completion of design studies. One prospective type is a side-channel spillway in the right abutment. Based on model studies for similar spillways, a "C" value of 3.8 can be attained. By substitution in the formula $Q = CLH^{3/2}$, a spillway 642 feet long will pass the spillway design flood at a surcharge of 10 feet. The design studies may prove it advisable to utilize a different type of spillway or different values of spillway length and surcharge but these will be comparable to those quoted herein.

20. Overload characteristics. - To determine the overload characteristics of the spillway, superfloods were computed, using

the forecast worst storm, and unit hydrographs distorted by increasing the peak discharge 100 and 200 percent. The distorted unit hydrographs (see Table I) and the superfloods are shown on Plate No. 22. The superfloods were routed through the natural valley storage and the surcharge storage, and over a spillway which will discharge 77,100 cubic feet per second at a 10-foot surcharge, and the resulting maximum discharges and surcharges are shown on Plate No. 23. As shown, a superflood computed from a unit hydrograph having a peak discharge 240 percent in excess of the empirical relations unit hydrograph can be passed by the spillway by encroaching on only 4 feet of the freeboard.

21. Volumetric safety factor. - For comparative purposes only, superfloods were computed using the adopted unit hydrographs and increasing the rainfall excess of the computed spillway flood by 50 and 100 percent, as shown on Plate No. 24. These volumetric superfloods were routed through the natural valley storage and the surcharge storage, and over a spillway which will discharge 77,100 cubic feet per second at a 10-foot surcharge. The results of this study are shown on Plate No. 25.

22. Freeboard.

a. Maximum wave height. - There are no records of maximum wave heights at existing reservoirs in this region. Accordingly, maximum predicted wave heights were determined by the Stevenson-Molitor formula given in Engineer Bulletin, R. & H. No. 9, 1938. The maximum fetch is 3.0 miles. The corresponding maximum wave height is 3.45 feet, for a wind velocity of 60 miles per hour.

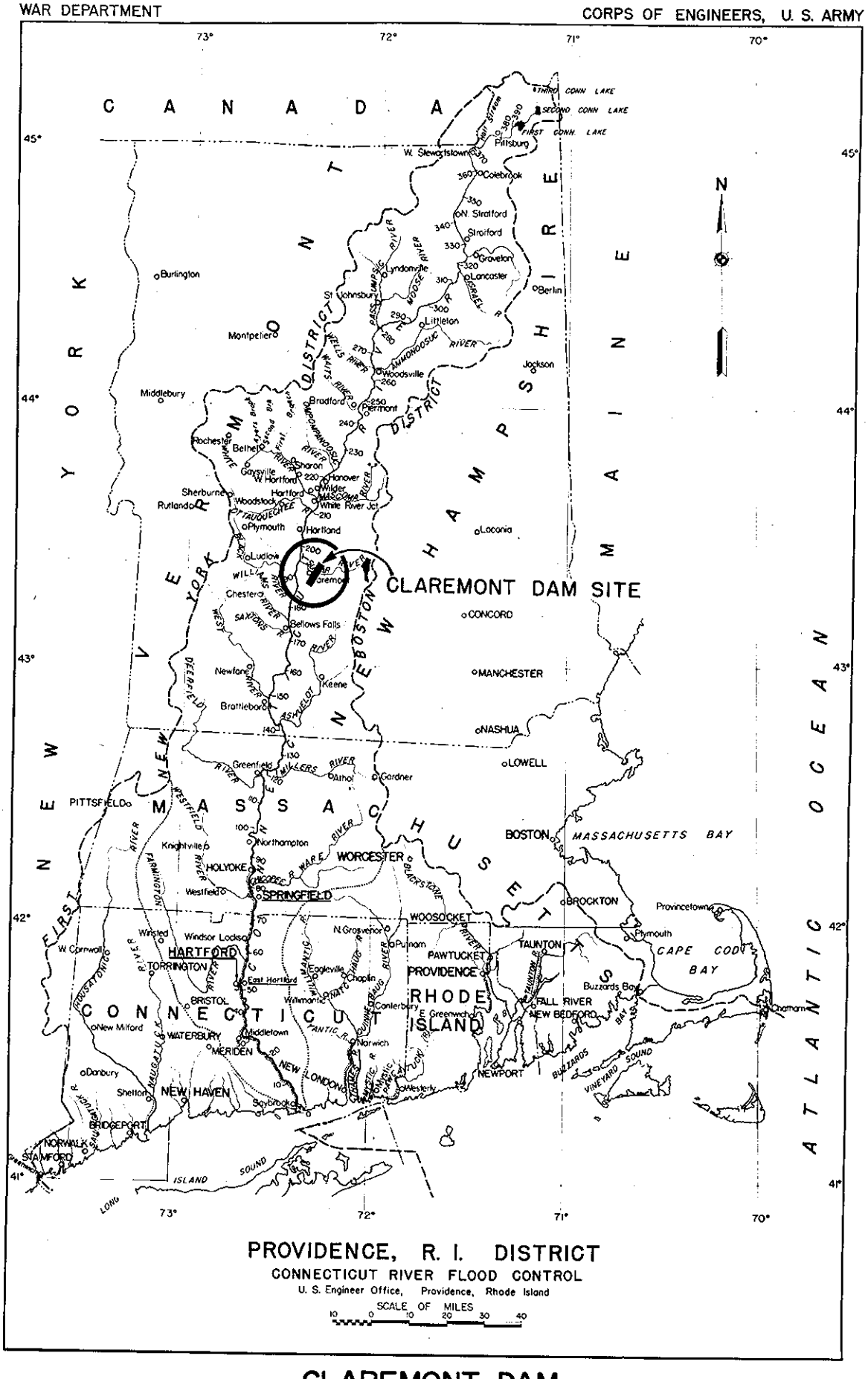
The reservoir extends southeast from the dam, while the prevailing maximum winds are from the northwest and west. Therefore, maximum wave heights are less likely to occur at the Claremont Dam than at one where the maximum fetch toward the dam parallels the direction of prevailing winds.

b. Ride-up. - Wave height plus ride-up, computed at 1.4 times the wave height, is 4.8 feet.

c. Set-up. - Wind set-up was computed from the formula published by the Lorentz Zuiderzee Commission and given in Engineer Bulletin, R. & H. No. 9, 1938. It has a maximum value of 0.3 foot. Because of the narrow zone of wind direction coincident with the maximum fetch, which is not in the direction of the prevailing winds, this item is considered negligible.

d. Selected freeboard. - Frost action will penetrate to a greater depth than 5 feet only under the most severe conditions, and moisture will rarely be present in the upper five feet of the dam. Also, at the time of year when maximum snow cover exists and when frost penetration will be deepest, a spillway flood will not require as high a surcharge as the adopted spillway design flood occurring without snow cover. On the basis of Paragraph b, above, and the foregoing, 5.0 feet has been selected for the freeboard above maximum surcharge.

23. Conclusions and recommendations. - A spillway design flood having a natural peak discharge of 81,200 cubic feet per second at the dam, as explained in Paragraph 15, satisfies the requirements as to method of determination and as to adequacy of its magnitude. It is recommended that this spillway design flood be adopted for design.



PROVIDENCE, R. I. DISTRICT

CONNECTICUT RIVER FLOOD CONTROL

U. S. Engineer Office, Providence, Rhode Island

SCALE OF MILES 10 0 10 20 30 40

CLAREMONT DAM

LOCATION MAP

PLATE NO. I

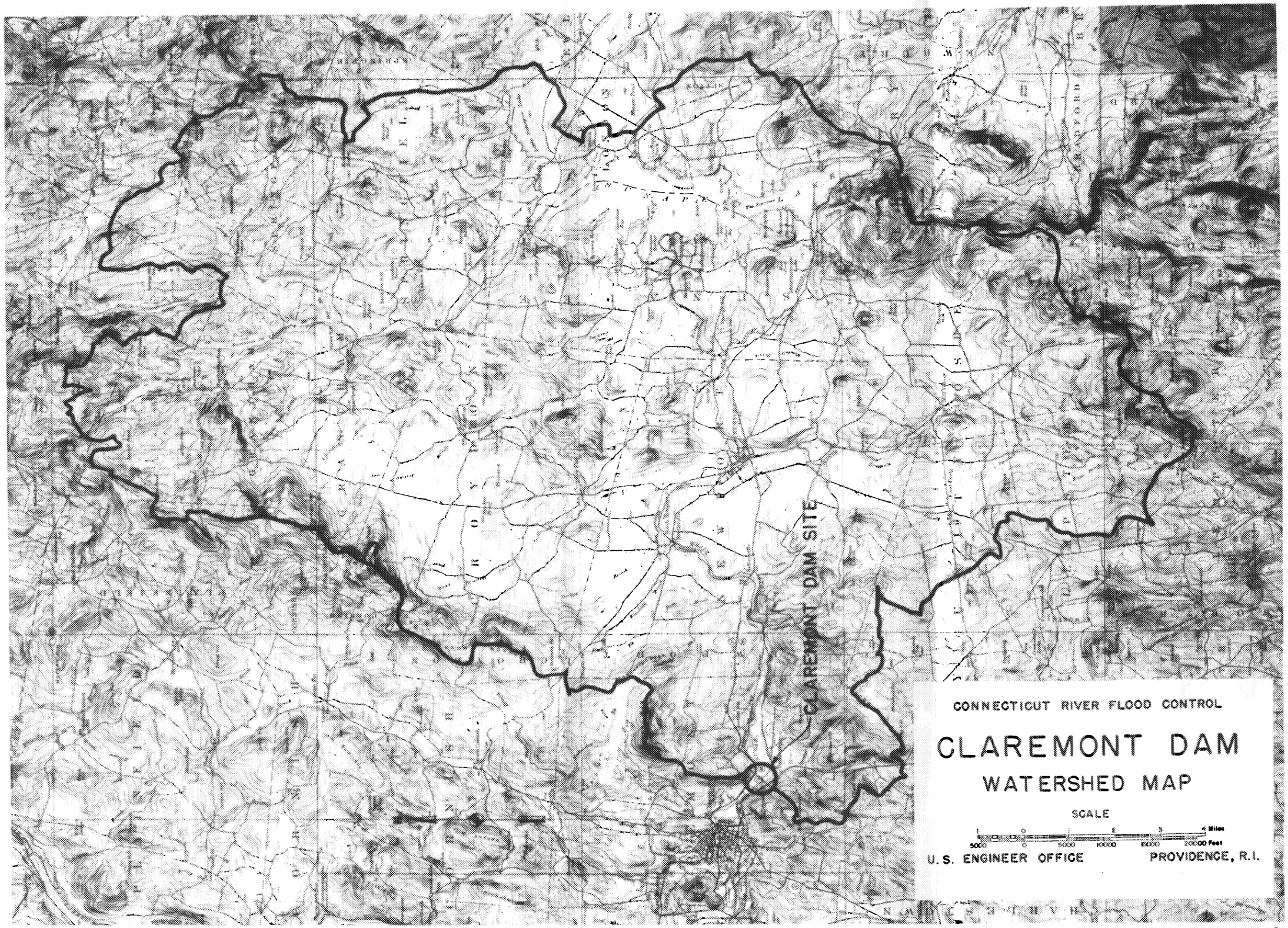
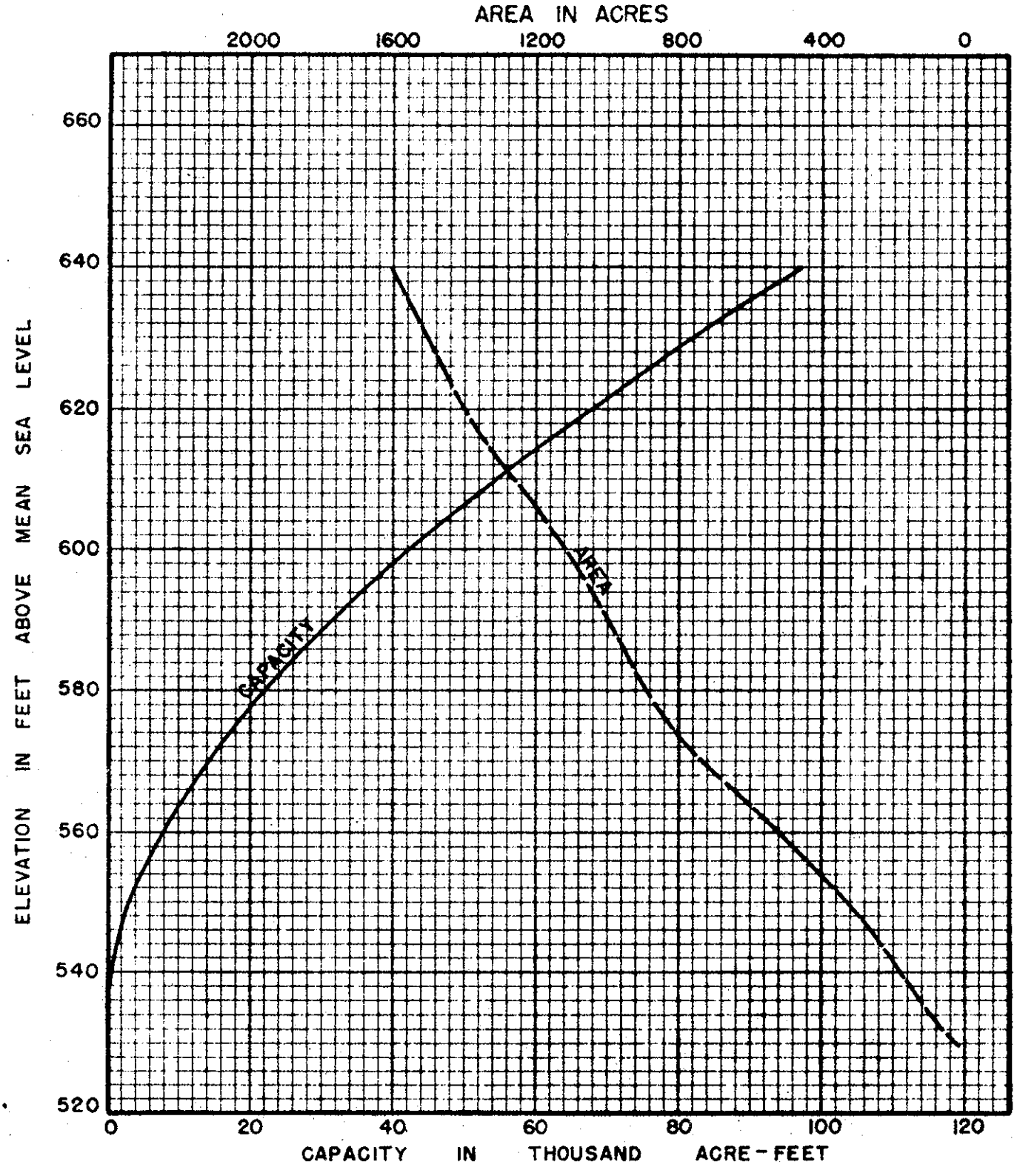

CLAREMONT DAM SITE
CONNECTICUT RIVER FLOOD CONTROL
CLAREMONT DAM
WATERSHED MAP
SCALE
U.S. ENGINEER OFFICE
PROVIDENCE, R.I.

PLATE NO. 2



SOURCE OF DATA - RESERVOIR SECTIONS OF OCT. 1939

CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT RESERVOIR

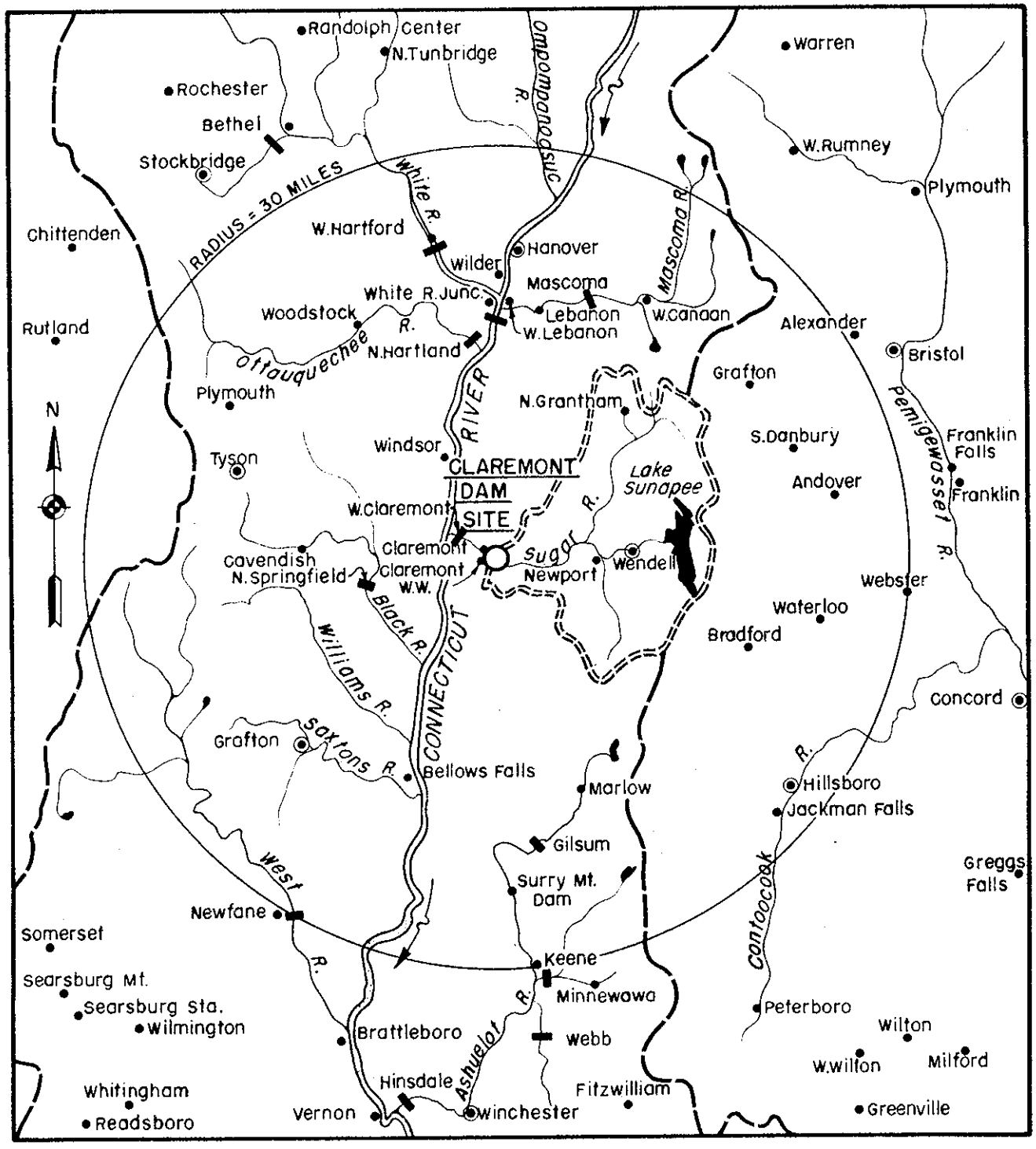
AREA AND CAPACITY CURVES

SUGAR RIVER, NEW HAMPSHIRE

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

MAR. 1940

PLATE NO. 3



LEGEND

- Rainfall station -non-recording gage
- Rainfall station -recording gage
- Stream gaging station
- Claremont Watershed
- Connecticut River Watershed

CONNECTICUT RIVER FLOOD CONTROL

RAINFALL AND STREAM GAGING STATIONS

IN VICINITY OF CLAREMONT WATERSHED

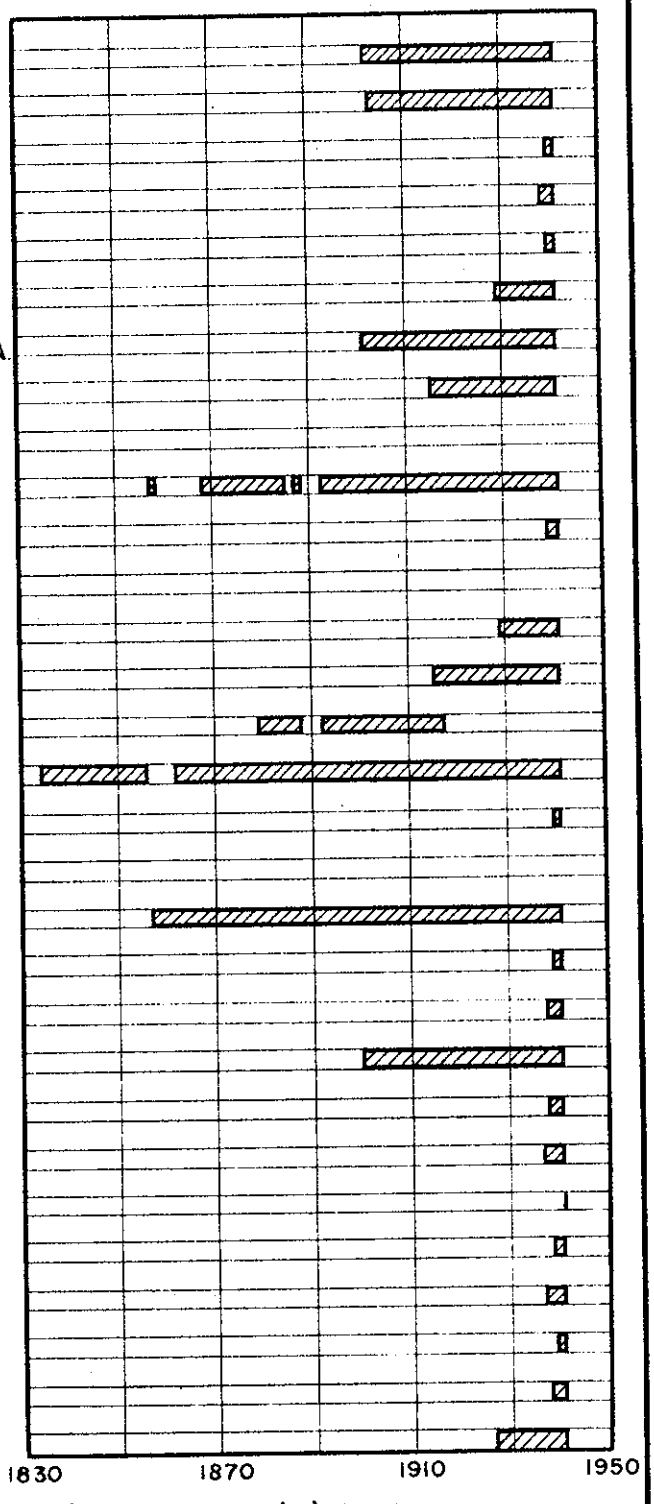
SCALE

10 MI. 0 10 MI. 20 MI.

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 4

BELLOWS FALLS,	VT.	N.E.P.A.
CAVENDISH,	VT.	C.V.P.S.C.
GRAFTON,	VT.	U.S.E.D.(P)
PLYMOUTH,	VT.	U.S.E.D.(P)
TYSON,	VT.	U.S.E.D.(P)
WEST HARTFORD,	VT.	U.S.W.B.
WHITE RIVER JUNCTION,	VT.	U.S.W.B-N.E.P.A.
WILDER,	VT.	N.E.P.A.
WINDSOR,	VT.	C.V.P.S.C.
WOODSTOCK,	VT.	U.S.W.B.
ANDOVER,	N.H.	U.S.E.D.(B)
BRADFORD,	N.H.	U.S.W.B.
CLAREMONT,	N.H.	C.V.P.S.C.
CLAREMONT,	N.H.	C.W.W.
GRAFTON,	N.H.	U.S.W.B.
HANOVER,	N.H.	S.O.D.
HILLSBORO,	N.H.	U.S.W.B.
JACKMAN FALLS,	N.H.	P.S.C.N.H.
KEENE,	N.H.	P.S.C.N.H.
LEBANON,	N.H.	C.A.A.
MARLOW,	N.H.	U.S.E.D.(P)
NEWPORT,	N.H.	N.W.W.
NORTH GRANTHAM,	N.H.	U.S.E.D.(P)
SOUTH DANBURY,	N.H.	U.S.E.D.(B)
SURRY MT. DAM,	N.H.	U.S.E.D.(P)
WATERLOO,	N.H.	U.S.E.D.(B)
WEBSTER,	N.H.	U.S.E.D.(B)
WENDELL,	N.H.	U.S.E.D.(P)
WEST CANAAN,	N.H.	U.S.E.D.(P)
WEST LEBANON,	N.H.	N.E.P.A.



U.S.E.D. – United States Engineer Department (P) Providence (B) Boston
U.S.W.B. – United States Weather Bureau
N.E.P.A. – New England Power Association
C.A.A. – Civil Aeronautics Authority
C.V.P.S.C. – Cent. Vt. Public Service Corp.
C.W.W. – Claremont Water Works
N.W.W. – Newport Water Works
S.O.D. – Shattuck Observatory-Dartmouth
P.S.C.N.H. – Public Service Co. of N.H.

CONNECTICUT RIVER FLOOD CONTROL

YEARS OF RECORD OF RAINFALL STATIONS

IN VICINITY OF CLAREMONT WATERSHED

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 5

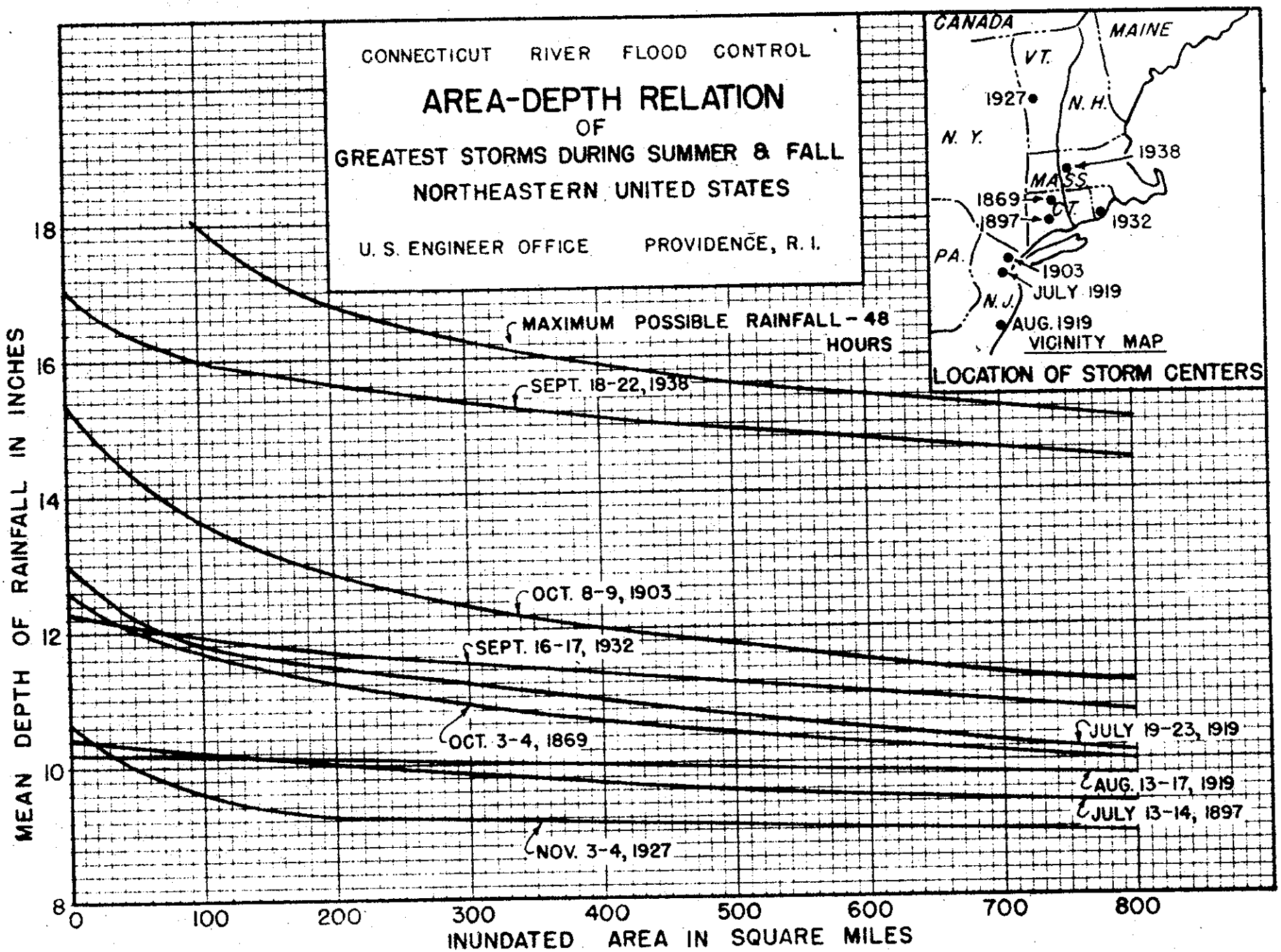

CONNECTICUT RIVER FLOOD CONTROL
AREA-DEPTH RELATION
OF
GREATEST STORMS DURING SUMMER & FALL
NORTHEASTERN UNITED STATES
U. S. ENGINEER OFFICE PROVIDENCE, R. I.
CANADA
MAINE
VT.
N. H.
N. Y.
MASS.
CT.
PA.
N. J.
1927
1938
1869
1897
1932
1903
JULY 1919
AUG. 1919
VICINITY MAP
LOCATION OF STORM CENTERS
MAXIMUM POSSIBLE RAINFALL - 48 HOURS
SEPT. 18-22, 1938
OCT. 8-9, 1903
SEPT. 16-17, 1932
OCT. 3-4, 1869
JULY 19-23, 1919
AUG. 13-17, 1919
JULY 13-14, 1897
NOV. 3-4, 1927
MEAN DEPTH OF RAINFALL IN INCHES
8
10
12
14
16
18
0
100
200
300
400
500
600
700
800
INUNDATED AREA IN SQUARE MILES

PLATE NO. 6

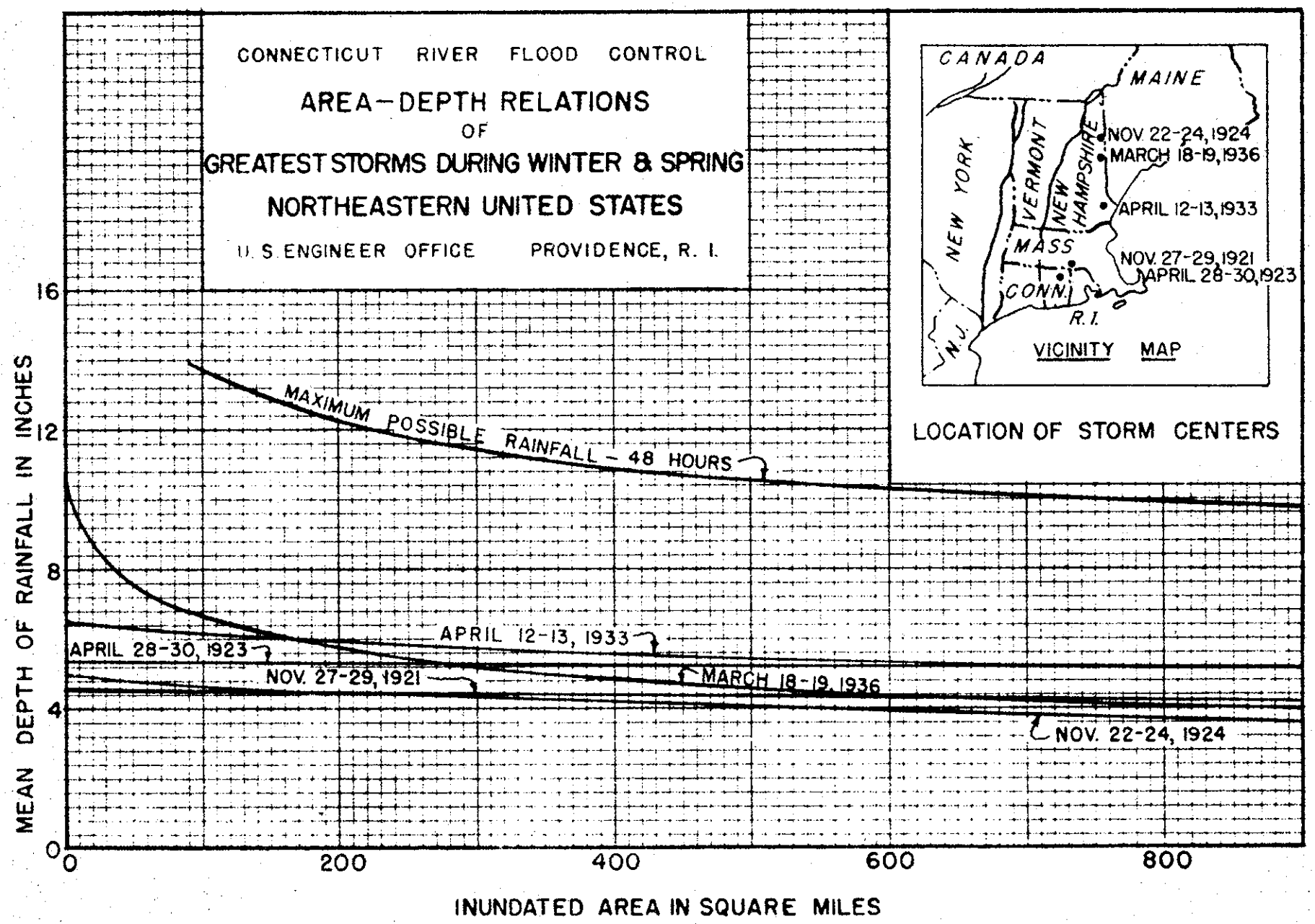
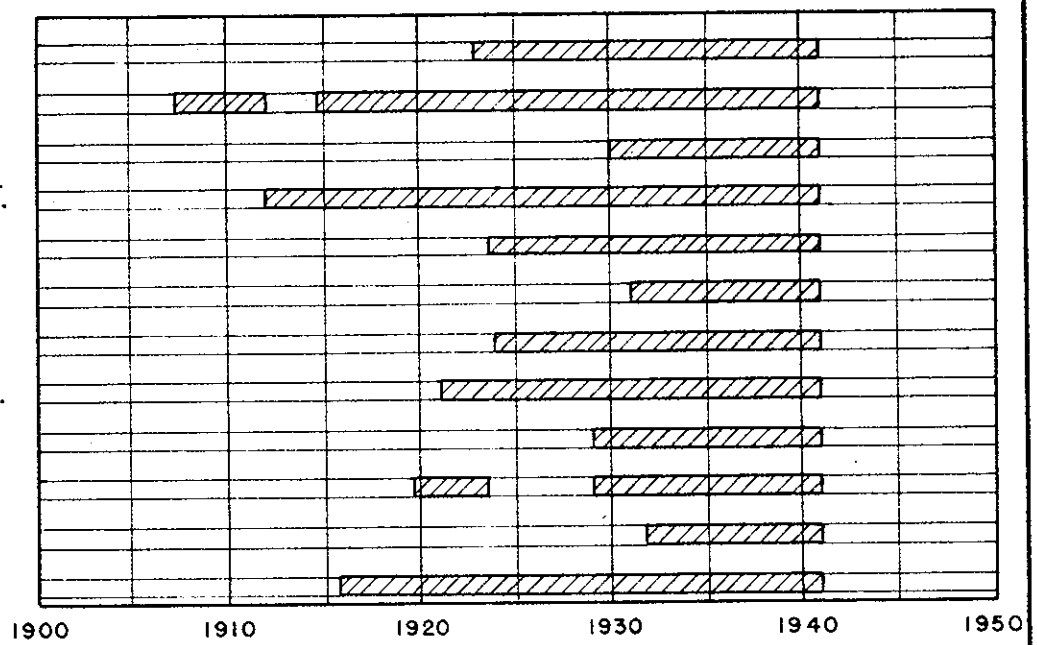

CONNECTICUT RIVER FLOOD CONTROL
AREA-DEPTH RELATIONS
OF
GREATEST STORMS DURING WINTER & SPRING
NORTHEASTERN UNITED STATES
U. S. ENGINEER OFFICE PROVIDENCE, R. I.
CANADA
MAINE
NEW YORK
VERMONT
NEW HAMPSHIRE
MASS
CONN.
R. I.
N. J.
NOV. 22-24, 1924
MARCH 18-19, 1936
APRIL 12-13, 1933
NOV. 27-29, 1921
APRIL 28-30, 1923
VICINITY MAP
LOCATION OF STORM CENTERS
MAXIMUM POSSIBLE RAINFALL - 48 HOURS
APRIL 12-13, 1933
APRIL 28-30, 1923
NOV. 27-29, 1921
MARCH 18-19, 1936
NOV. 22-24, 1924
MEAN DEPTH OF RAINFALL IN INCHES
0
4
8
12
16
0
200
400
600
800
INUNDATED AREA IN SQUARE MILES

PLATE NO. 7

ASHUELOT RIVER NEAR GILSUM, N.H.
ASHUELOT RIVER AT HINSDALE, N.H.
BLACK RIVER AT NORTH SPRINGFIELD, VT.
CONNECTICUT RIVER AT WHITE RIVER JUNCTION, VT.
MASCOMA RIVER AT MASCOMA, N.H.
OTTAUQUECHEE RIVER AT NORTH HARTLAND, VT.
OTTER BROOK NEAR KEENE, N.H.
SOUTH BRANCH OF ASHUELOT RIVER AT WEBB, N.H.
SUGAR RIVER AT WEST CLAREMONT, N.H.
WEST RIVER AT NEWFANE, VT.
WHITE RIVER AT BETHEL, VT.
WHITE RIVER AT WEST HARTFORD, VT.



CONNECTICUT RIVER FLOOD CONTROL

YEARS OF RECORD OF STREAM GAGING STATIONS

IN VICINITY OF CLAREMONT WATERSHED

U. S. ENGINEER OFFICE PROVIDENCE, R. I.

PLATE NO. 8

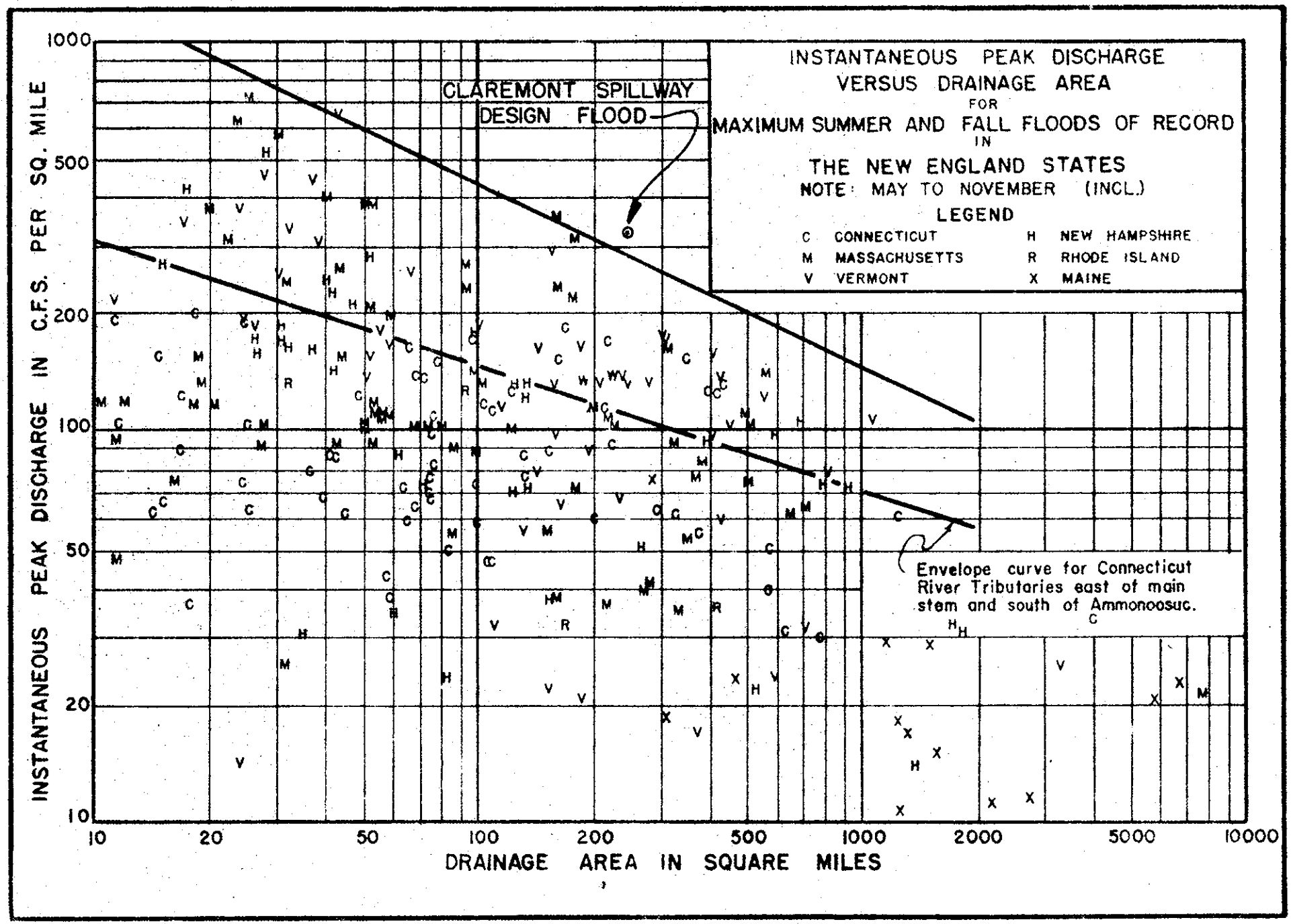

INSTANTANEOUS PEAK DISCHARGE
VERSUS DRAINAGE AREA
FOR
MAXIMUM SUMMER AND FALL FLOODS OF RECORD
IN
THE NEW ENGLAND STATES
NOTE: MAY TO NOVEMBER (INCL.)
LEGEND
C CONNECTICUT
M MASSACHUSETTS
V VERMONT
H NEW HAMPSHIRE
R RHODE ISLAND
X MAINE
CLAREMONT SPILLWAY
DESIGN FLOOD
Envelope curve for Connecticut River Tributaries east of main stem and south of Ammonoosuc.
INSTANTANEOUS PEAK DISCHARGE IN C.F.S. PER SQ. MILE
1000
500
200
100
50
20
10
10
20
50
100
200
500
1000
2000
5000
10000
DRAINAGE AREA IN SQUARE MILES

PLATE NO. 9

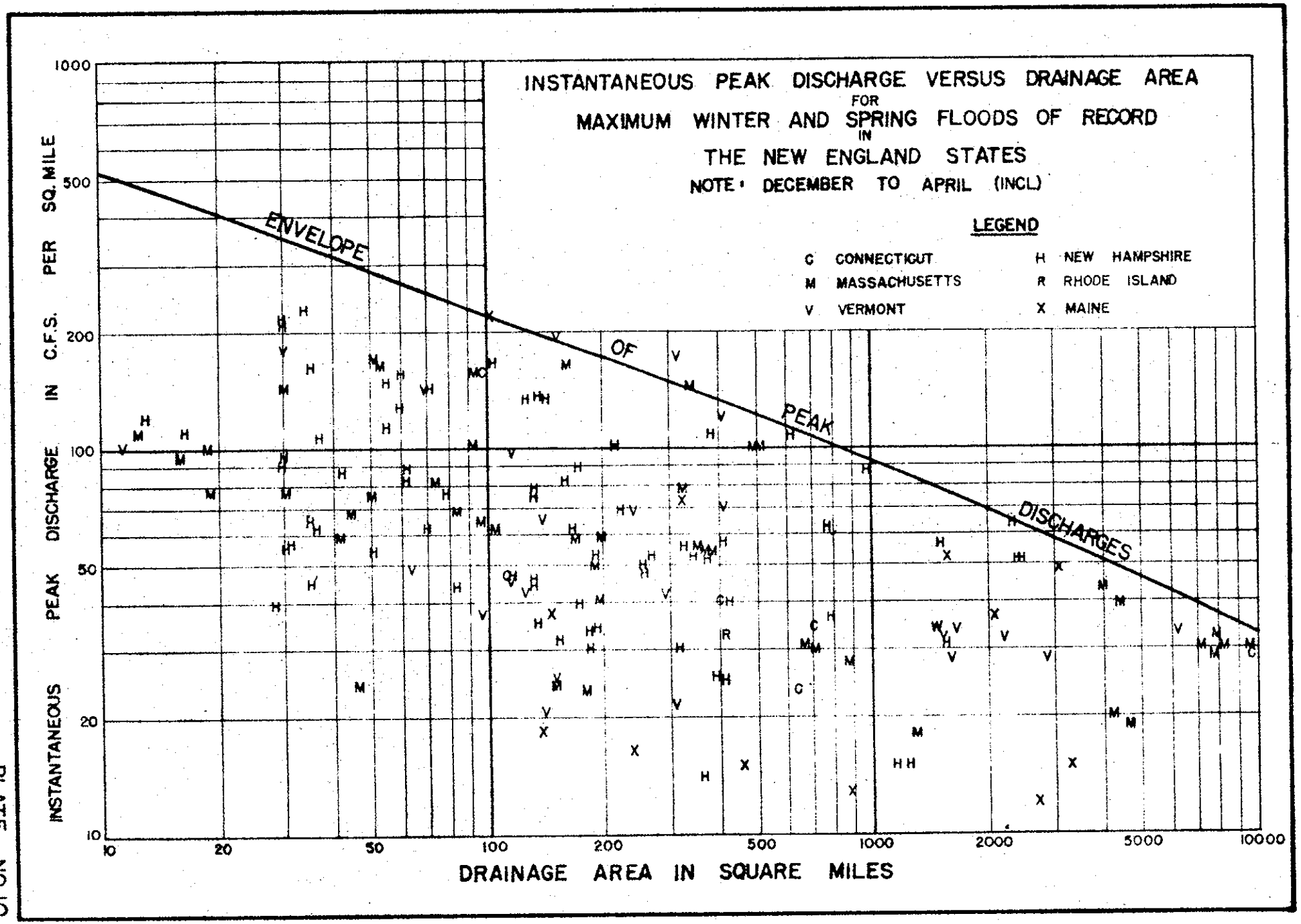
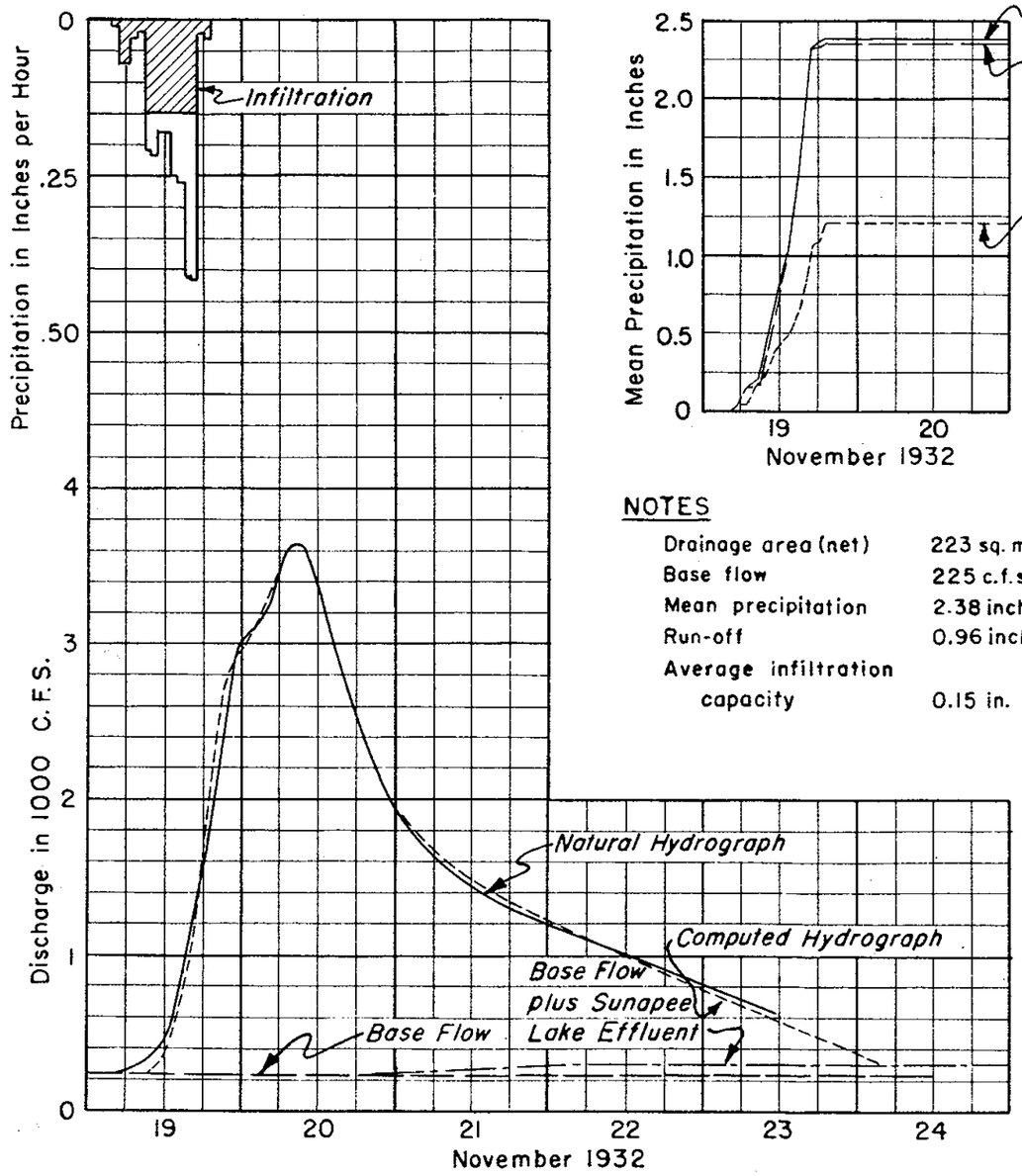
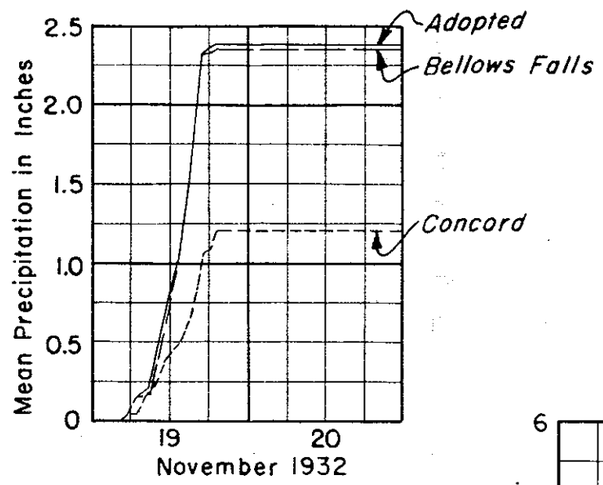

INSTANTANEOUS PEAK DISCHARGE VERSUS DRAINAGE AREA
FOR
MAXIMUM WINTER AND SPRING FLOODS OF RECORD
IN
THE NEW ENGLAND STATES
NOTE: DECEMBER TO APRIL (INCL)
LEGEND
C CONNECTICUT
M MASSACHUSETTS
V VERMONT
H NEW HAMPSHIRE
R RHODE ISLAND
X MAINE
ENVELOPE OF PEAK DISCHARGES
INSTANTANEOUS PEAK DISCHARGE IN C.F.S. PER SQ. MILE
1000
500
200
100
50
20
10
10
20
50
100
200
500
1000
2000
5000
10000
DRAINAGE AREA IN SQUARE MILES

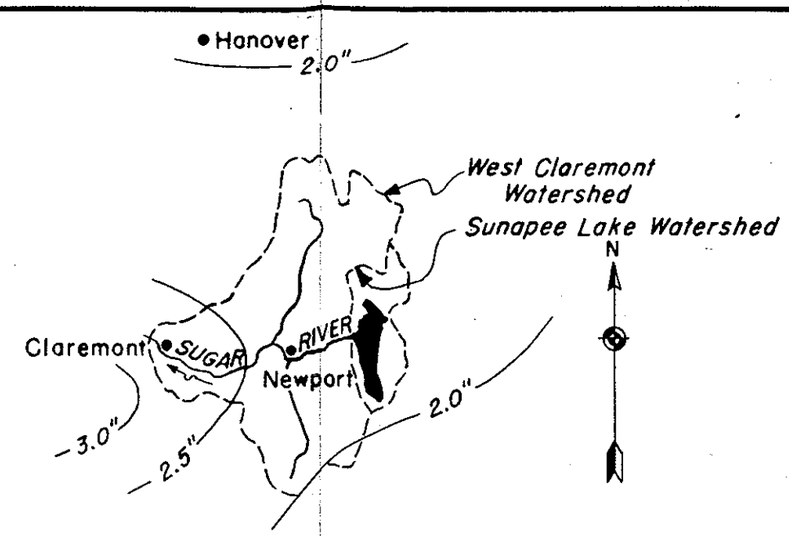
PLATE NO. 10



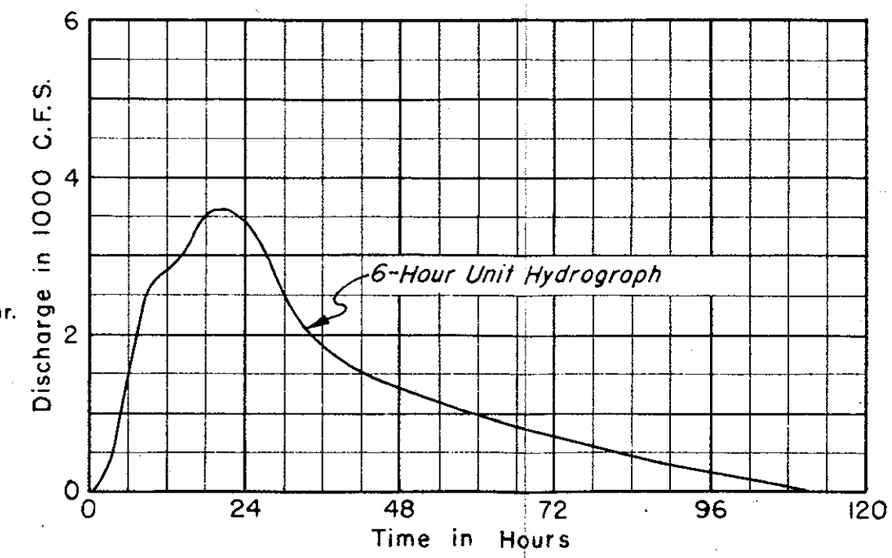


NOTES

Drainage area (net)	223 sq. mi.
Base flow	225 c.f.s.
Mean precipitation	2.38 inches
Run-off	0.96 inches
Average infiltration capacity	0.15 in. per hr.



ISOHYETAL MAP



CONNECTICUT RIVER FLOOD CONTROL

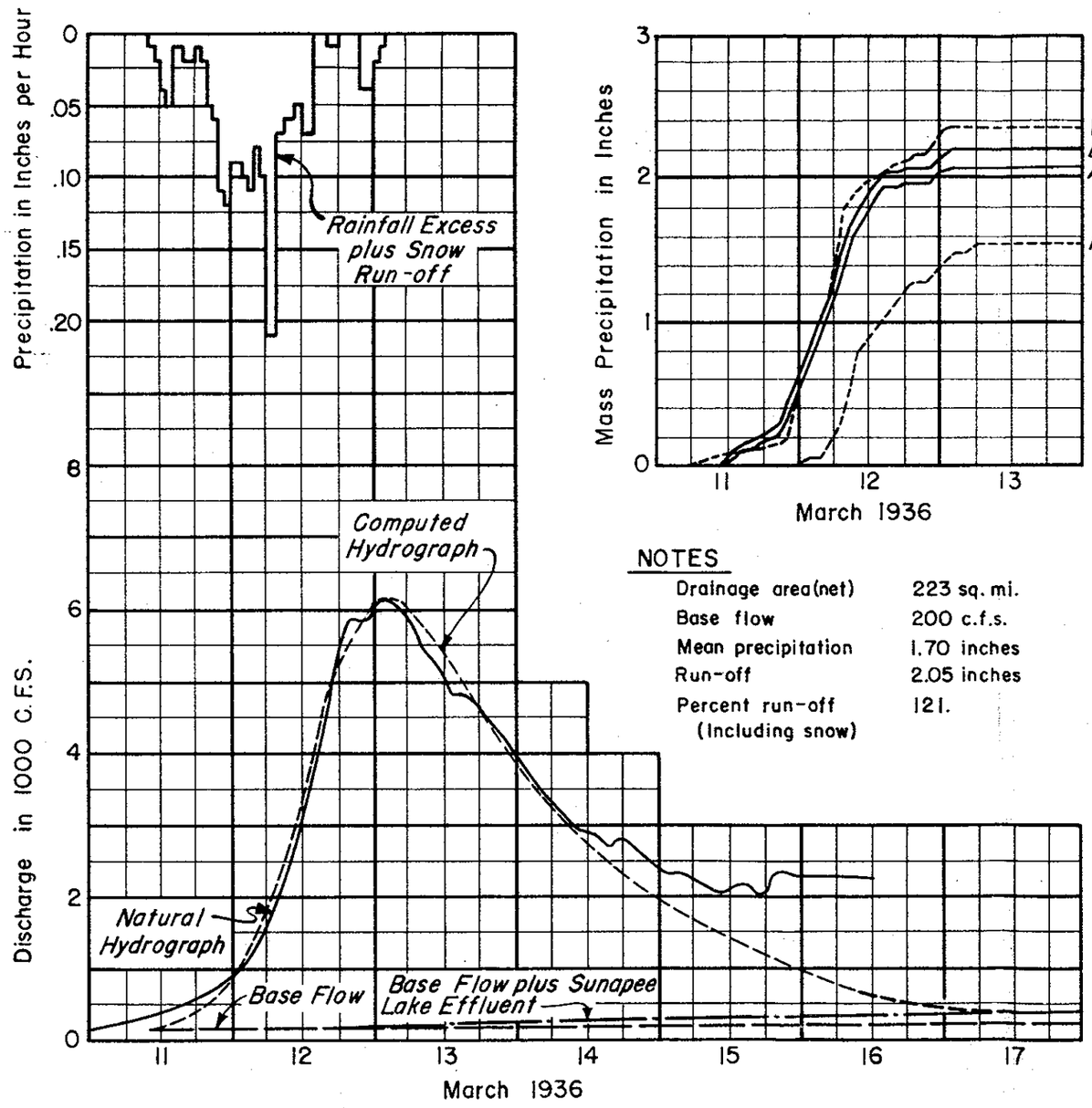
SUGAR RIVER AT WEST CLAREMONT, N. H.

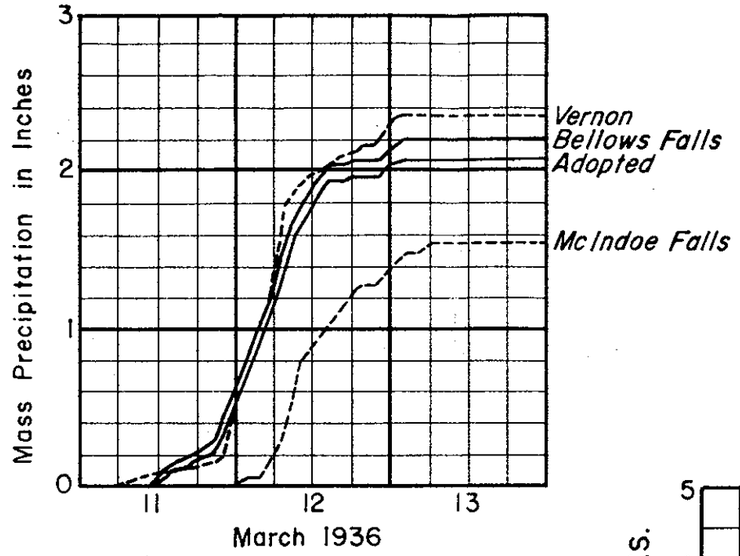
DERIVATION OF UNIT HYDROGRAPH

STORM OF NOVEMBER 1932

U.S. ENGINEER OFFICE PROVIDENCE, R. I.

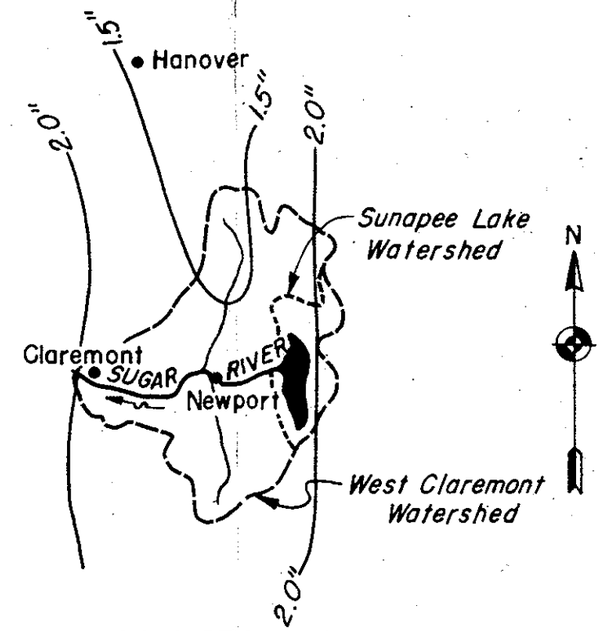
PLATE NO. 11



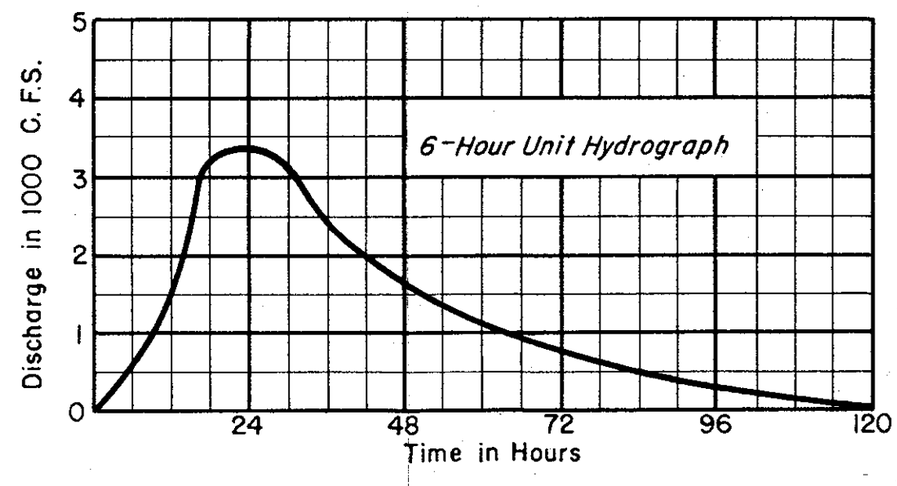


NOTES

Drainage area (net)	223 sq. mi.
Base flow	200 c.f.s.
Mean precipitation	1.70 inches
Run-off	2.05 inches
Percent run-off (including snow)	121.



ISOHYETAL MAP



CONNECTICUT RIVER FLOOD CONTROL

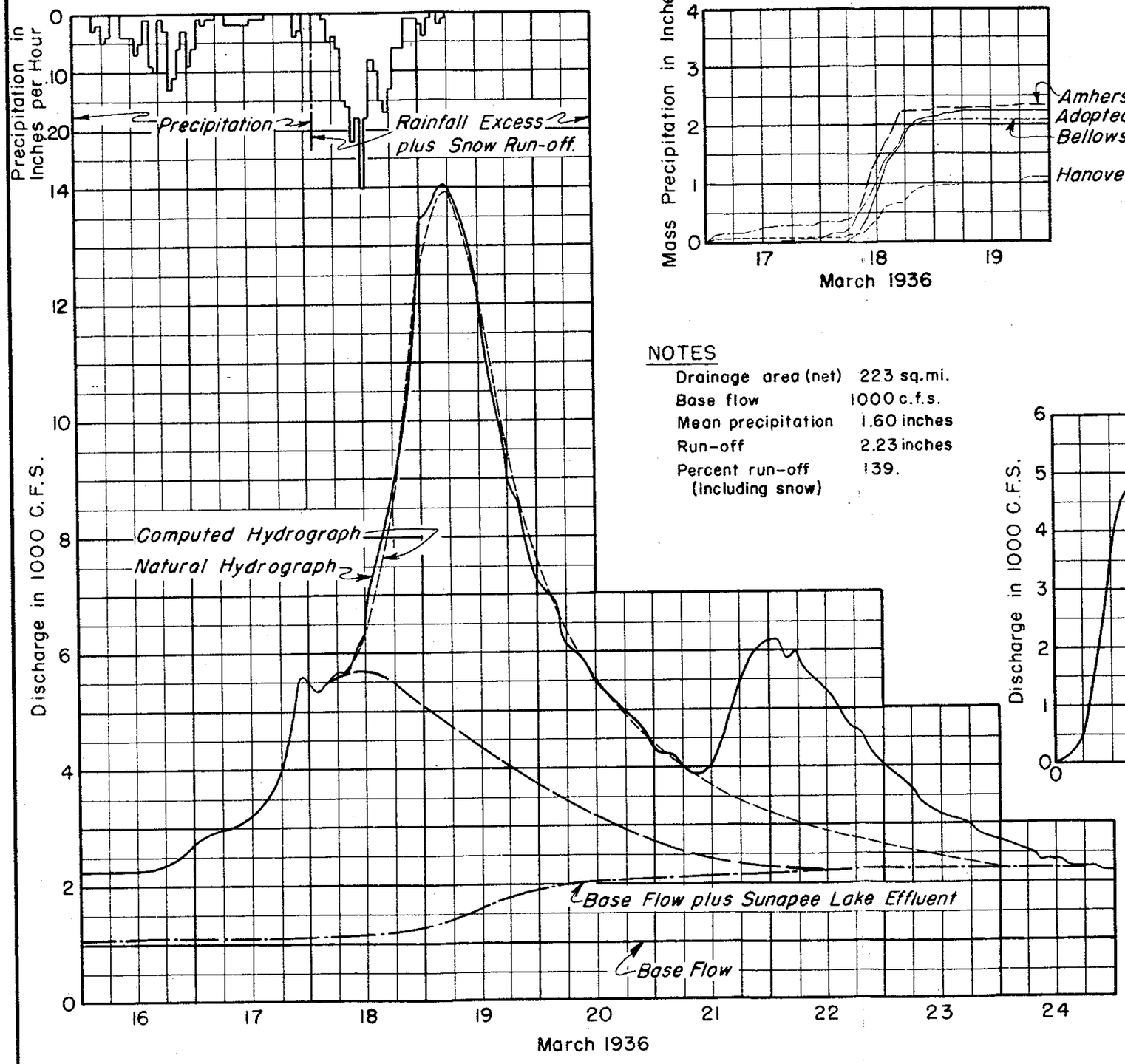
SUGAR RIVER AT WEST CLAREMONT, N.H.

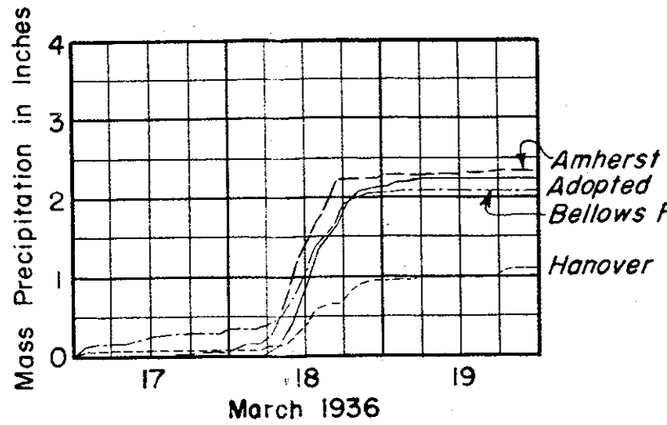
DERIVATION OF UNIT HYDROGRAPH

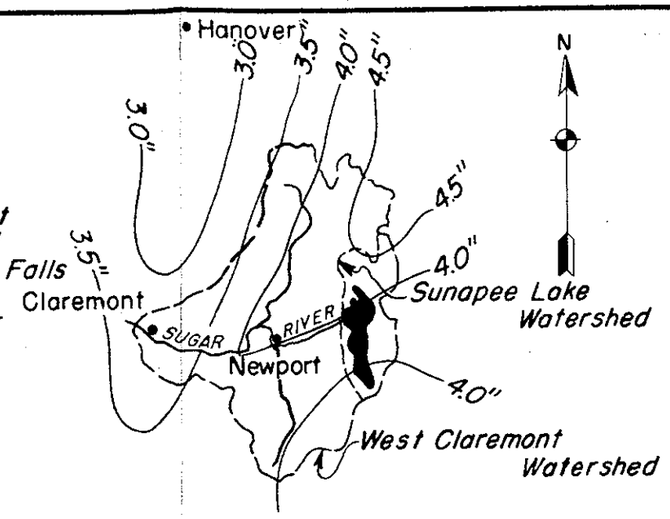
STORM OF MARCH 11-12, 1936

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 12





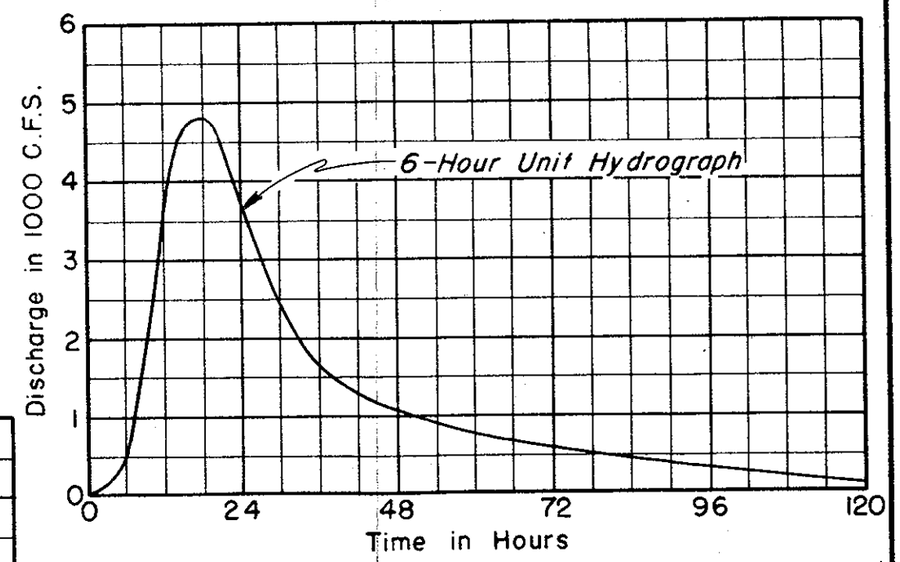


ISOHYETAL MAP

Covering period of March 16-22, 1936

NOTES

Drainage area (net)	223 sq.mi.
Base flow	1000 c.f.s.
Mean precipitation	1.60 inches
Run-off	2.23 inches
Percent run-off (including snow)	139.



CONNECTICUT RIVER FLOOD CONTROL

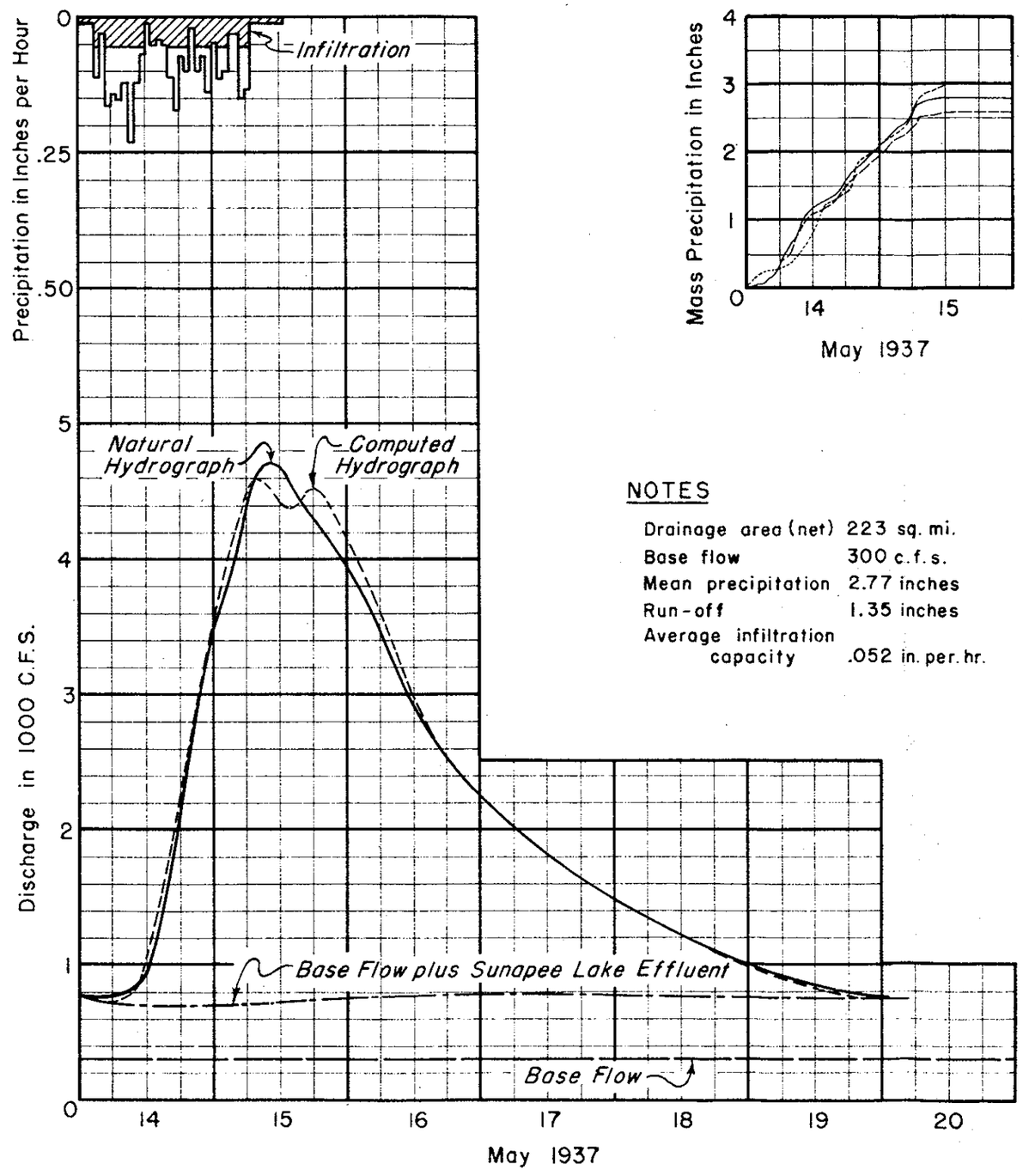
SUGAR RIVER AT WEST CLAREMONT, N.H.

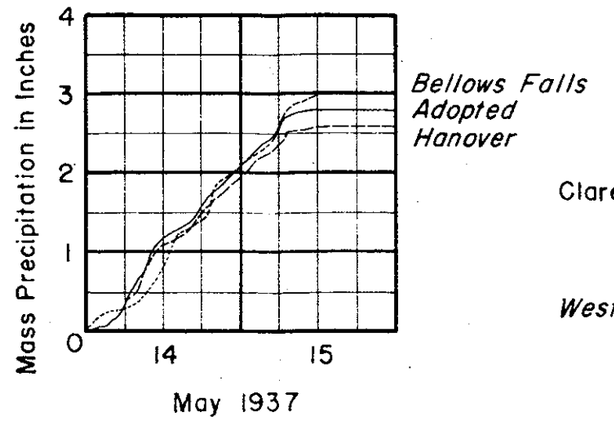
DERIVATION OF UNIT HYDROGRAPH

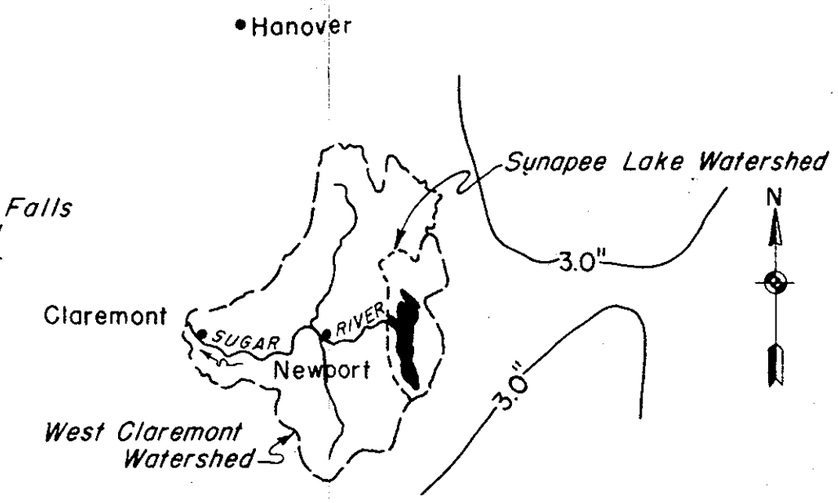
STORM OF MARCH 18, 1936

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 13



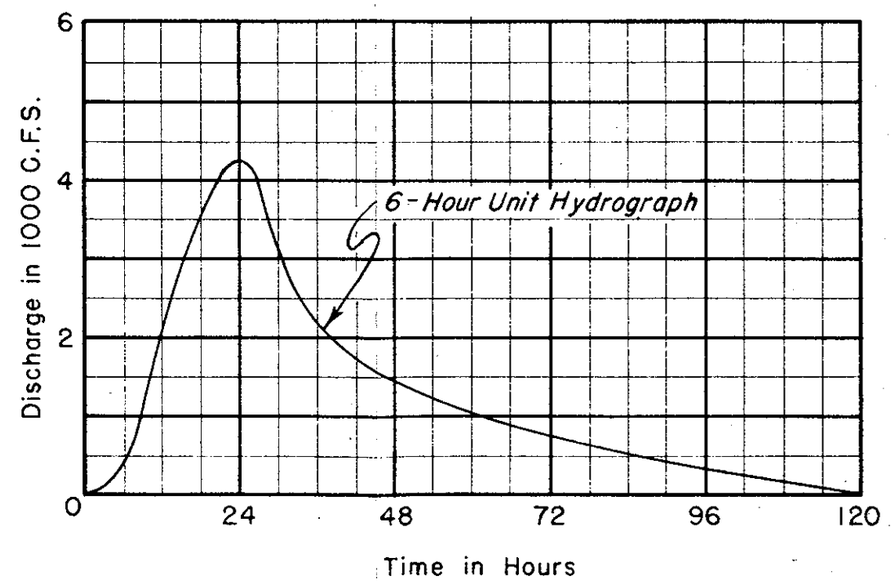




ISOHYETAL MAP

NOTES

Drainage area (net)	223 sq. mi.
Base flow	300 c.f.s.
Mean precipitation	2.77 inches
Run-off	1.35 inches
Average infiltration capacity	.052 in. per. hr.



CONNECTICUT RIVER FLOOD CONTROL

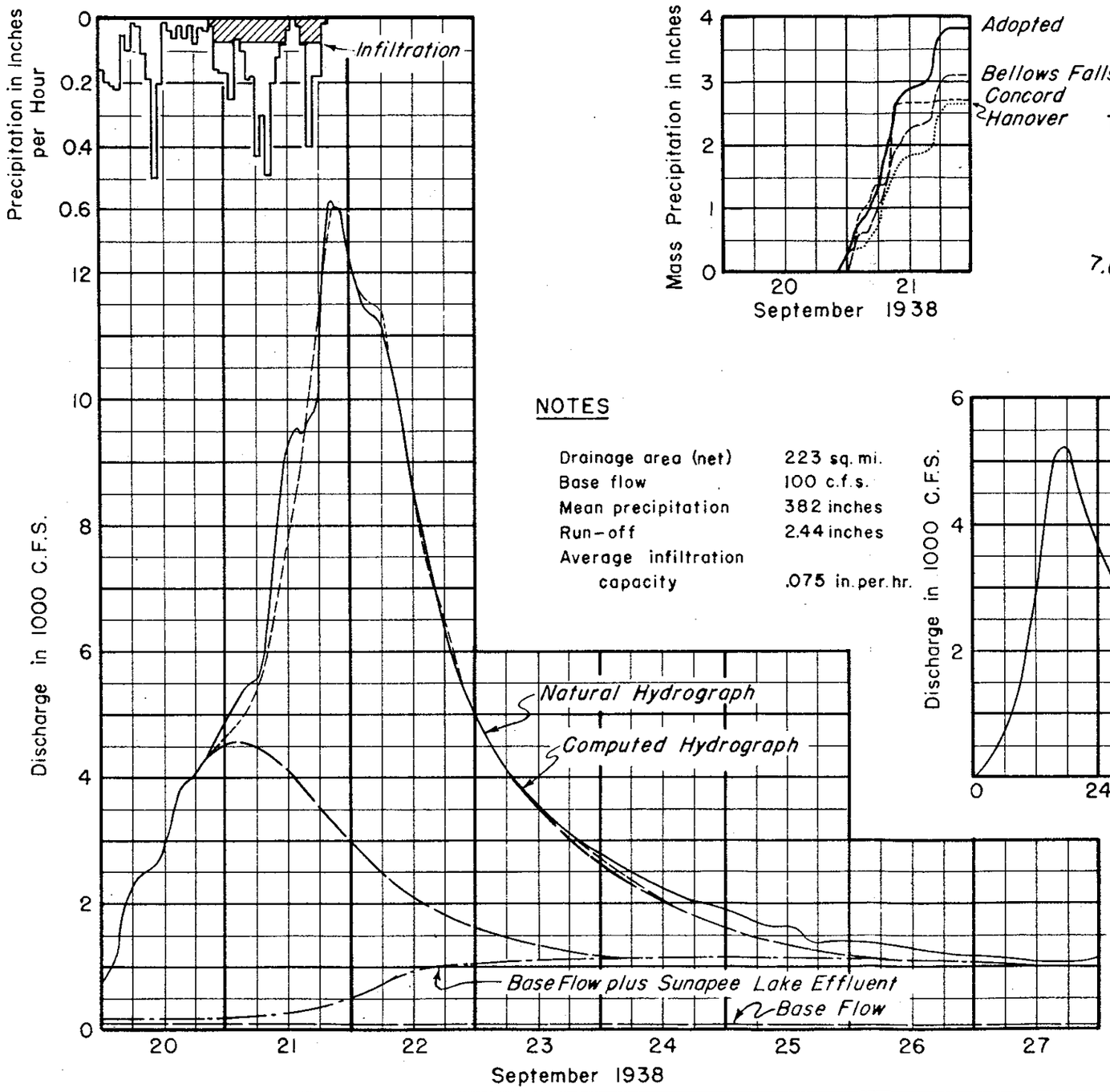
SUGAR RIVER AT WEST CLAREMONT, N.H.

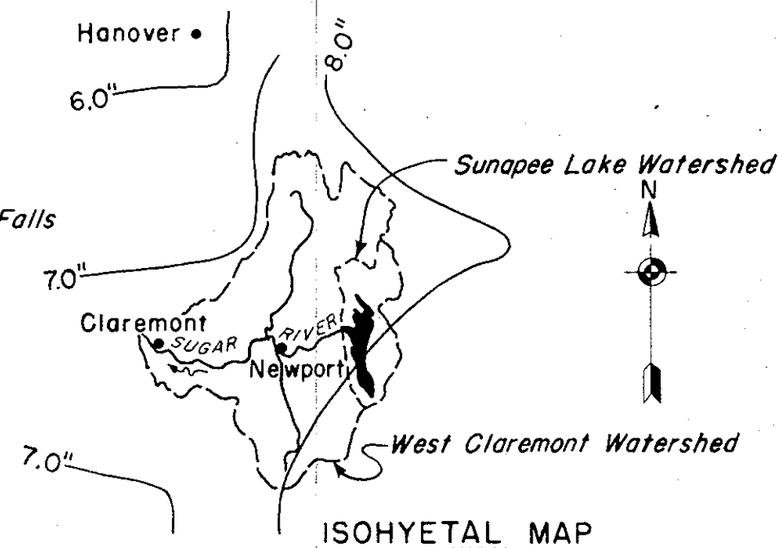
DERIVATION OF UNIT HYDROGRAPH

STORM OF MAY 1937

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 14



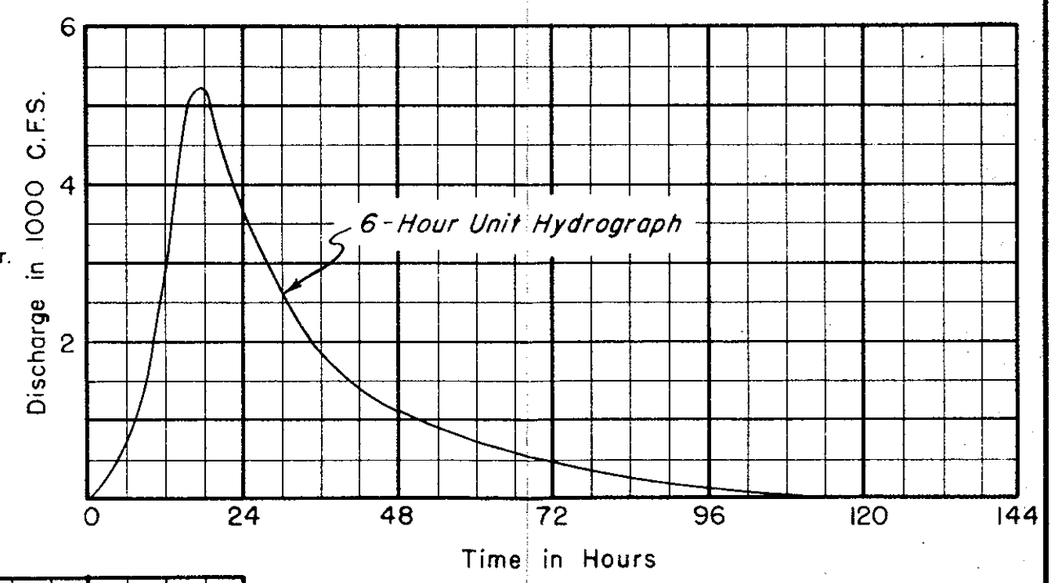


ISOHYETAL MAP

Covering period of Sept. 17-22, 1938

NOTES

Drainage area (net)	223 sq. mi.
Base flow	100 c.f.s.
Mean precipitation	382 inches
Run-off	2.44 inches
Average infiltration capacity	.075 in. per. hr.



CONNECTICUT RIVER FLOOD CONTROL

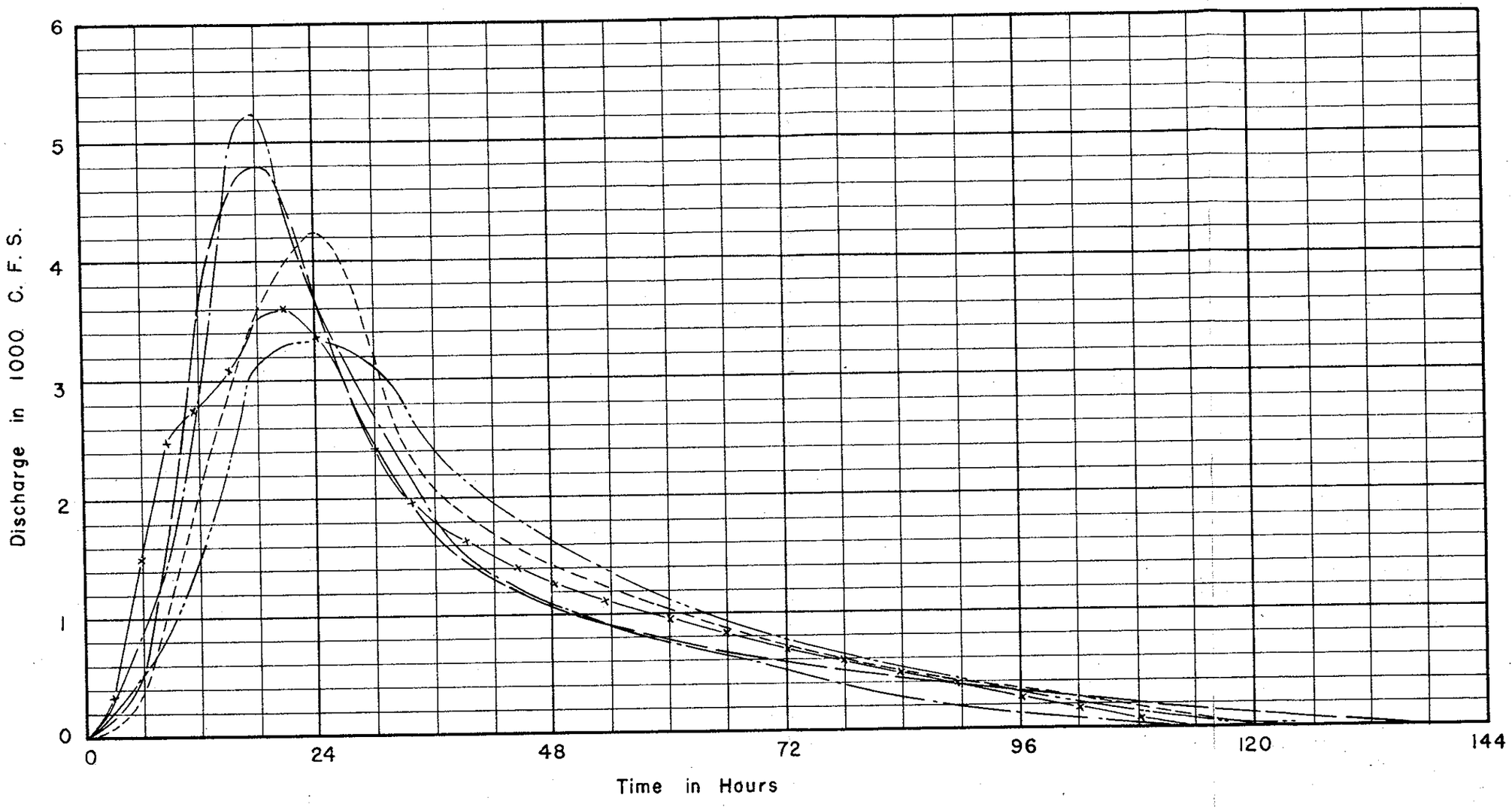
SUGAR RIVER AT WEST CLAREMONT, N.H.

DERIVATION OF UNIT HYDROGRAPH

STORM OF SEPTEMBER 1938

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 15



LEGEND

—·—·— Sept. 1938 (ADOPTED)

— — — — — May 1937

—— —— —— March 18, 1936

—··—··— March 11, 1936

—x—x— November 1932

NOTE

Unit hydrographs computed for net drainage area of 223 sq. mi.
(Gross drainage area = 269 sq. mi.)

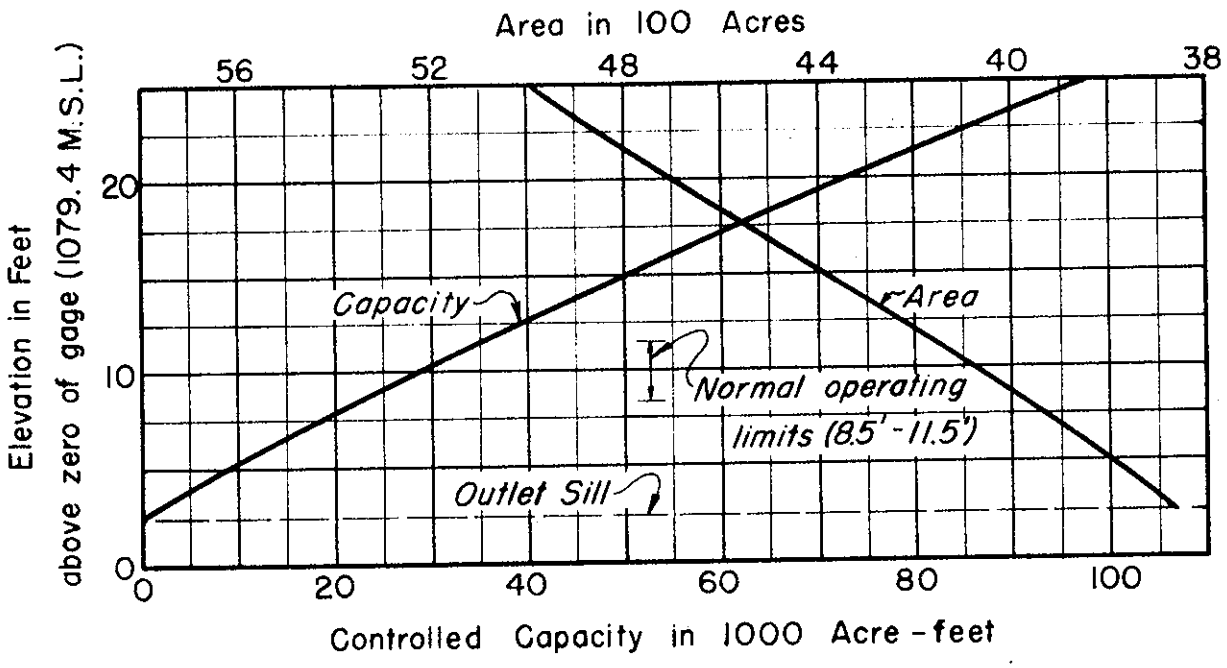
CONNECTICUT RIVER FLOOD CONTROL

SUGAR RIVER AT WEST CLAREMONT, N.H.

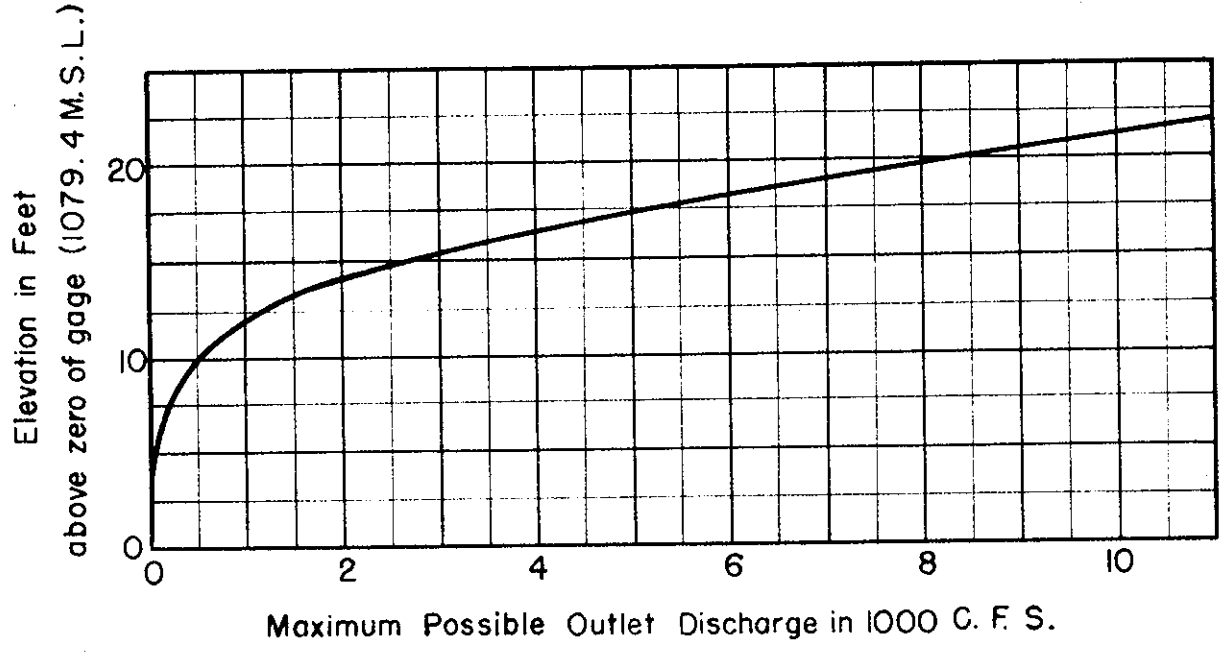
COMPUTED UNIT HYDROGRAPHS

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 16



AREA AND CAPACITY CURVES



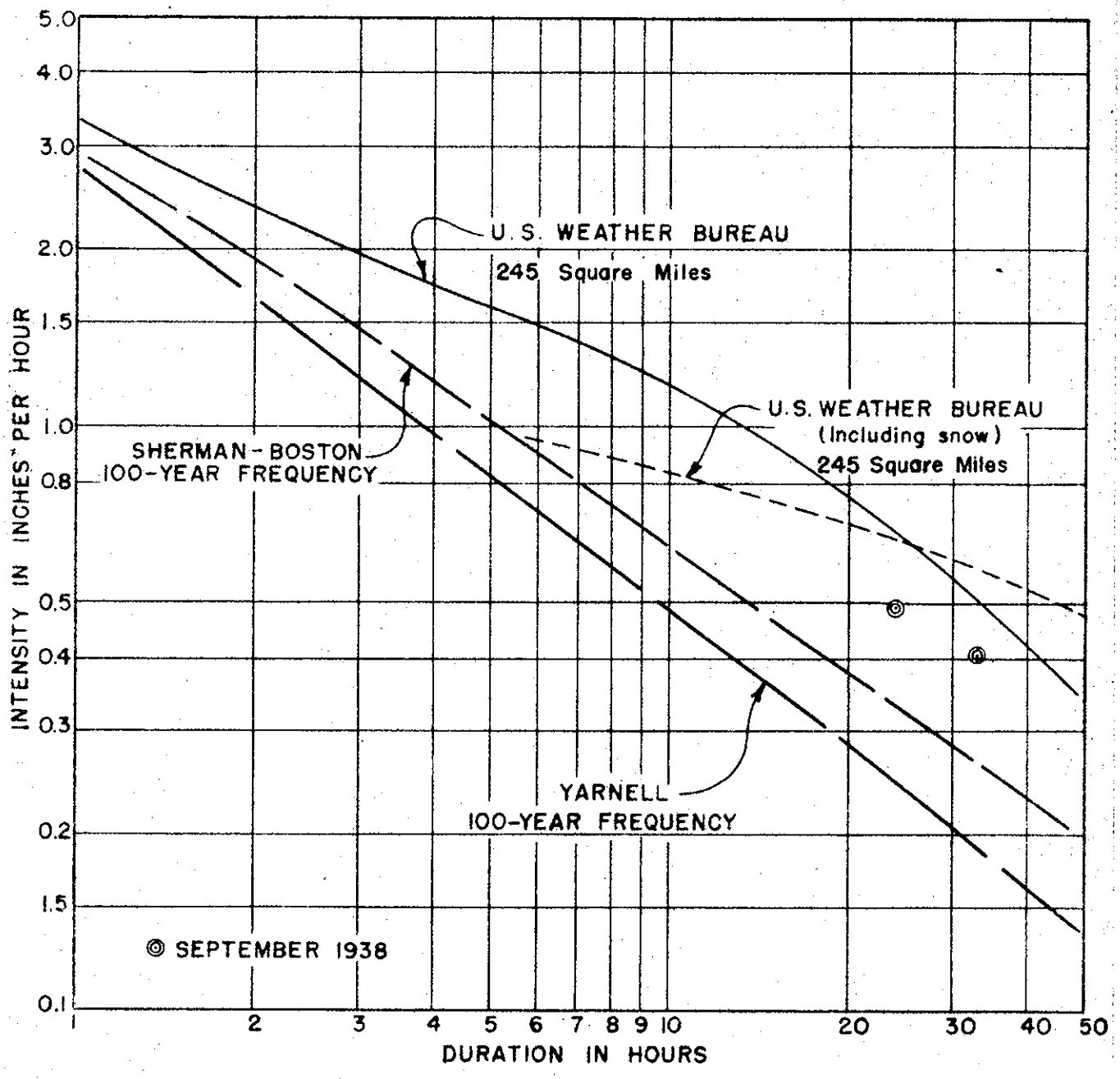
OUTLET RATING CURVE

CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

OPERATION CHARACTERISTICS OF SUNAPEE LAKE

U. S. ENGINEER OFFICE PROVIDENCE, R. I.



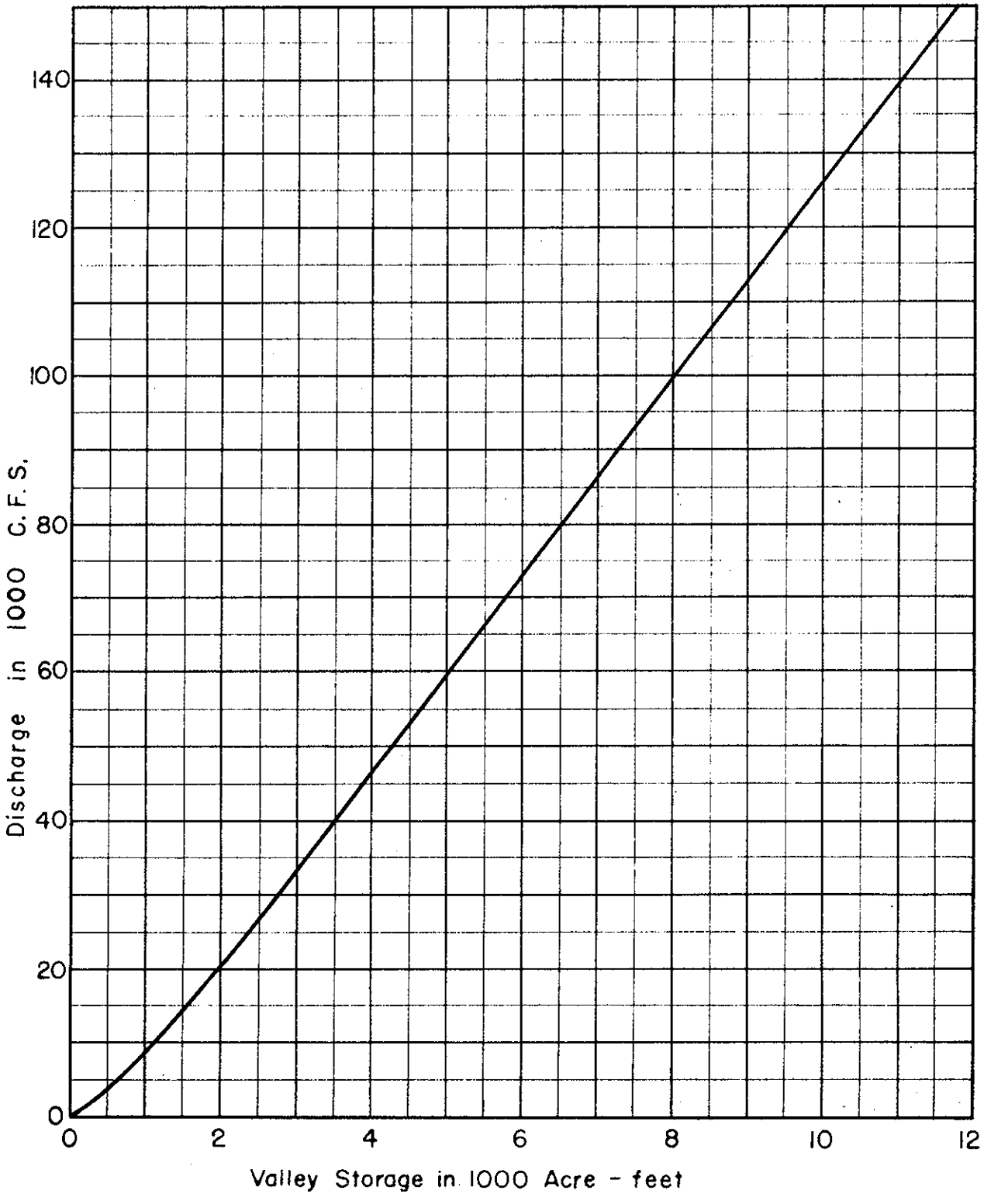
CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

MAXIMUM RAINFALL INTENSITY VERSUS DURATION

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 18

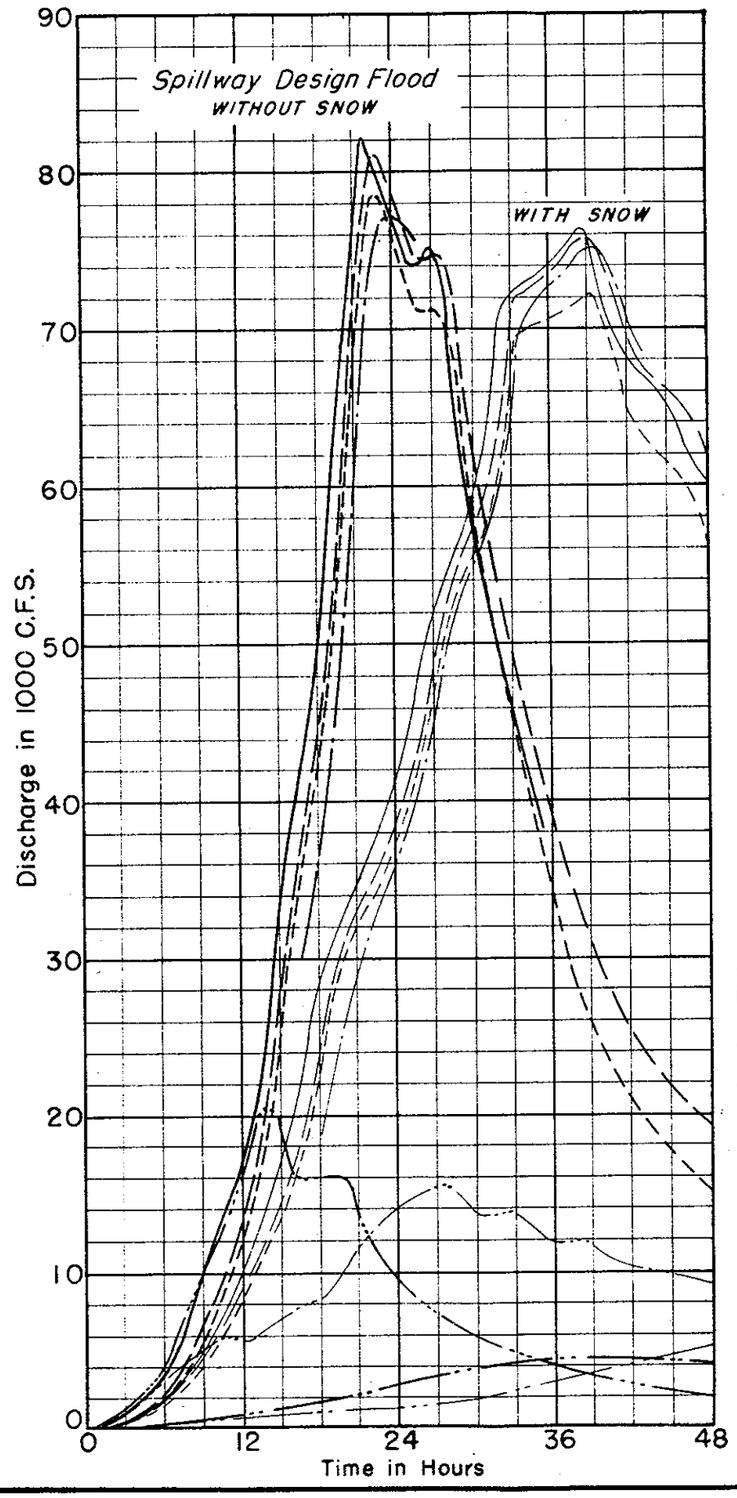


CONNECTICUT RIVER FLOOD CONTROL

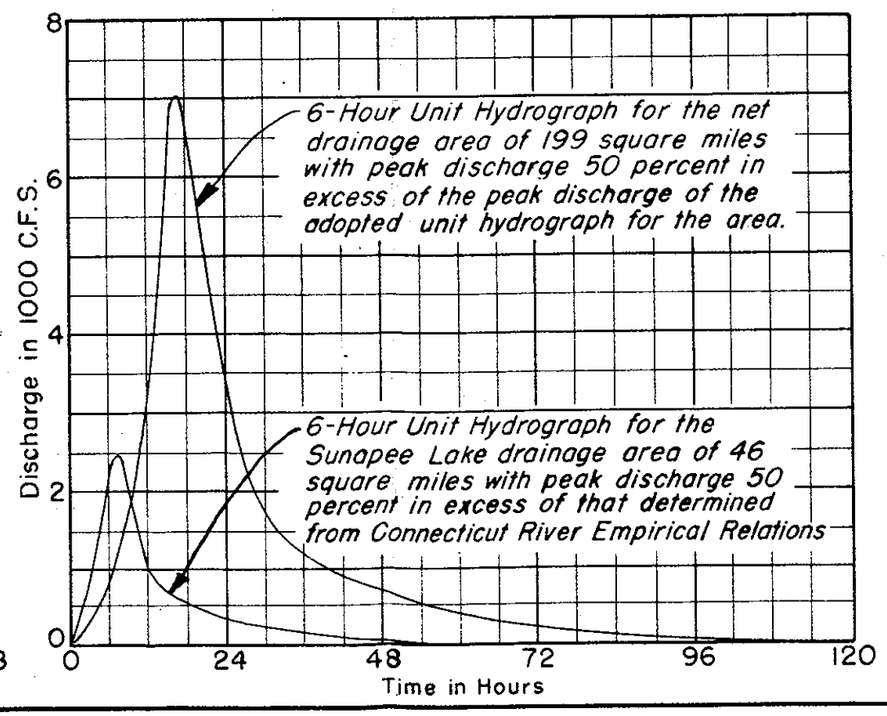
CLAREMONT DAM

VALLEY STORAGE CHARACTERISTICS

U. S. ENGINEER OFFICE PROVIDENCE, R. I.



PRECIPITATION – RUN-OFF DATA									
WITHOUT SNOW									
Period (hours)	Net D. A. – 199 Sq. Mi.			Sunapee Lake D.A. - 46 Sq.Mi.			Total D. A. – 245 Sq.Mi.		
	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)
0-6	0.10	0.10	.0	0.10	0.10	.0	0.10	0.10	.0
6-12	0.25	0.25	.0	0.25	0.25	.0	0.25	0.25	.0
12-18	2.00	0.30	1.7	2.00	0.30	1.7	2.00	0.30	1.7
18-24	9.10	0.30	8.8	7.50	0.30	7.2	8.80	0.30	8.5
24-30	4.00	0.30	3.7	4.00	0.30	3.7	4.00	0.30	3.7
30-36	1.10	0.30	0.8	1.10	0.30	0.8	1.10	0.30	0.8
36-42	0.25	0.25	.0	0.25	0.25	.0	0.25	0.25	.0
42-48	0.10	0.10	.0	0.10	0.10	.0	0.10	0.10	.0
Totals	16.90	1.90	15.0	15.30	1.90	13.4	16.50	1.90	14.7
WITH SNOW (Snow release included with precipitation)									
0-6	2.0		2.0	1.6		1.6	1.8		1.8
6-12	2.4		2.4	1.9		1.9	2.3		2.3
12-18	3.3		3.3	2.6		2.6	3.1		3.1
18-24	5.9		5.9	4.6		4.6	5.7		5.7
24-30	3.9		3.9	3.1		3.1	3.8		3.8
30-36	2.6		2.6	2.1		2.1	2.6		2.6
36-42	2.2		2.2	1.7		1.7	2.2		2.2
42-48	2.0		2.0	1.5		1.5	1.8		1.8
Totals	24.3	0	24.3	19.1	0	19.1	23.3	0	23.3



LEGEND

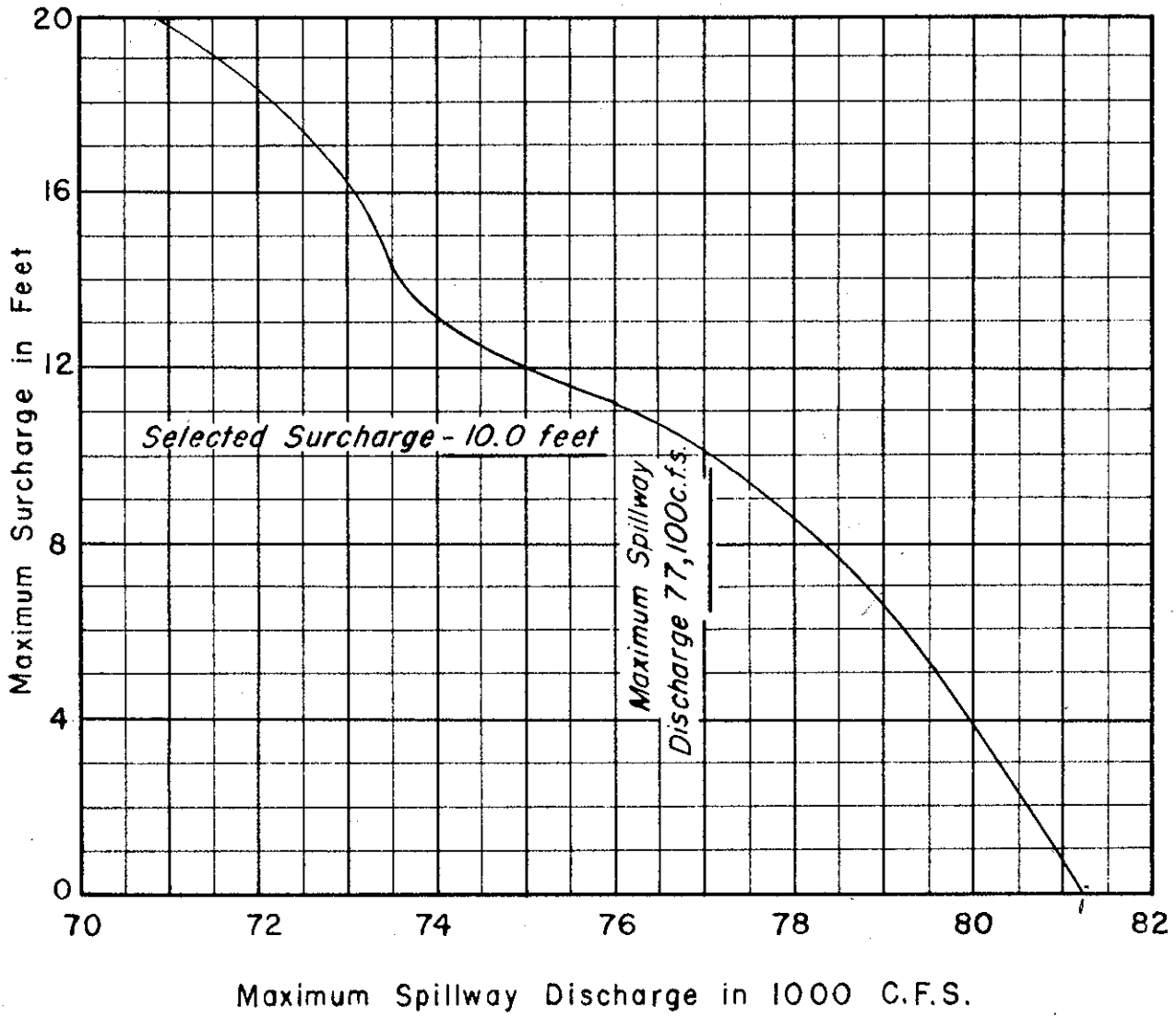
- Natural hydrograph - Sunapee Lake
- Sunapee Lake effluent routed to dam site
- Natural hydrograph - net area - 199 square miles
- Total natural hydrograph at dam site
- Inflow hydrograph
- Spillway discharge

CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

SPILLWAY DESIGN FLOOD

U. S. ENGINEER OFFICE PROVIDENCE, R. I.



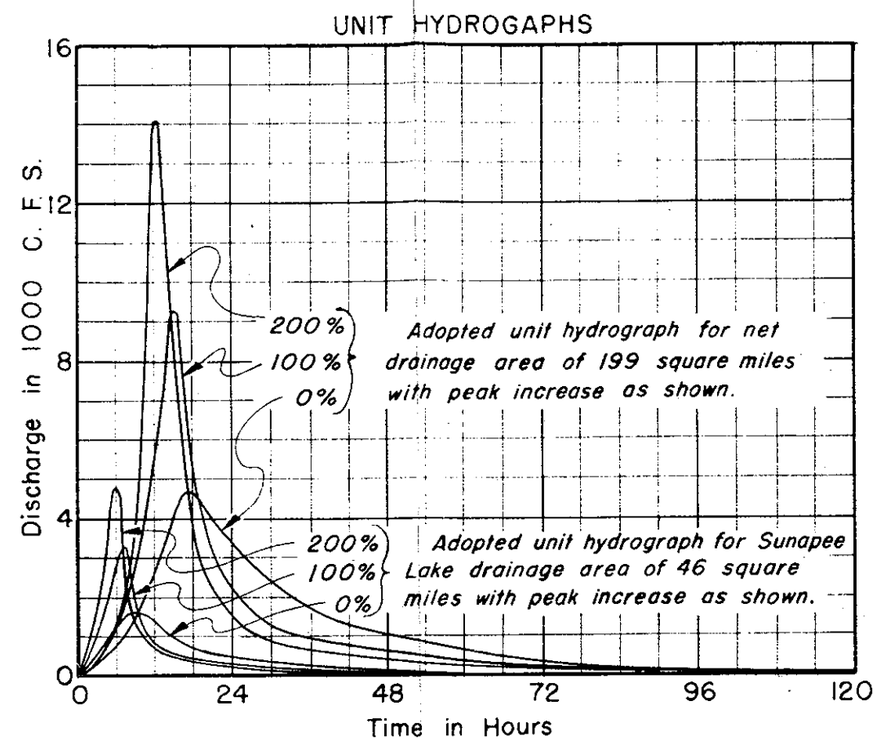
CONNECTICUT RIVER FLOOD CONTROL

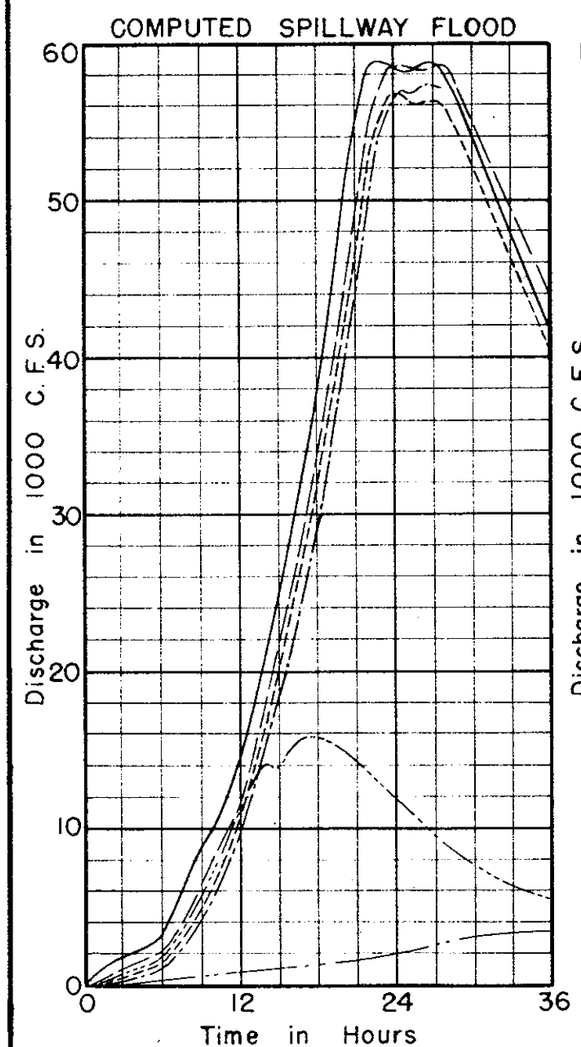
CLAREMONT DAM

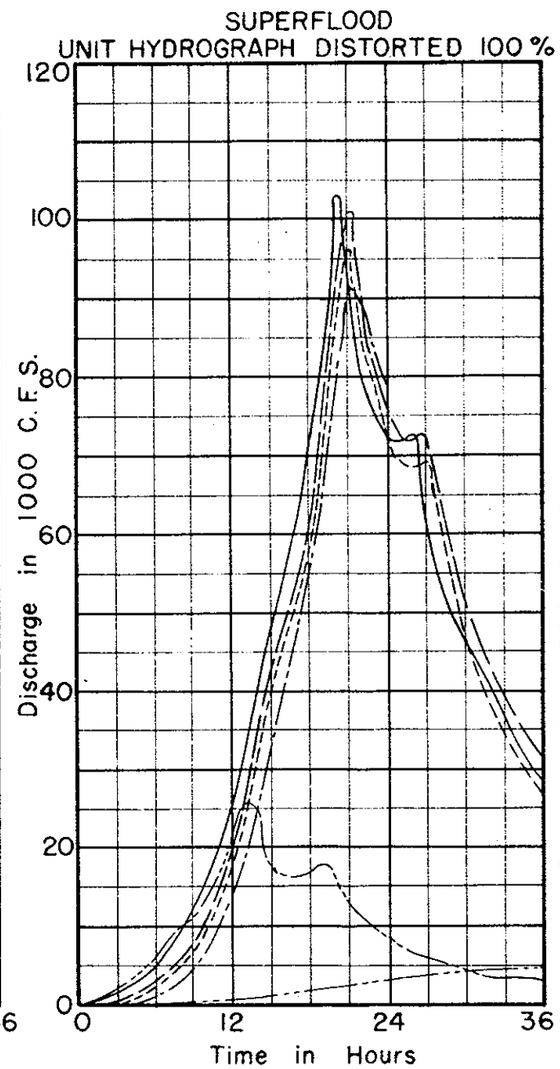
MAXIMUM SURCHARGE VS. DISCHARGE

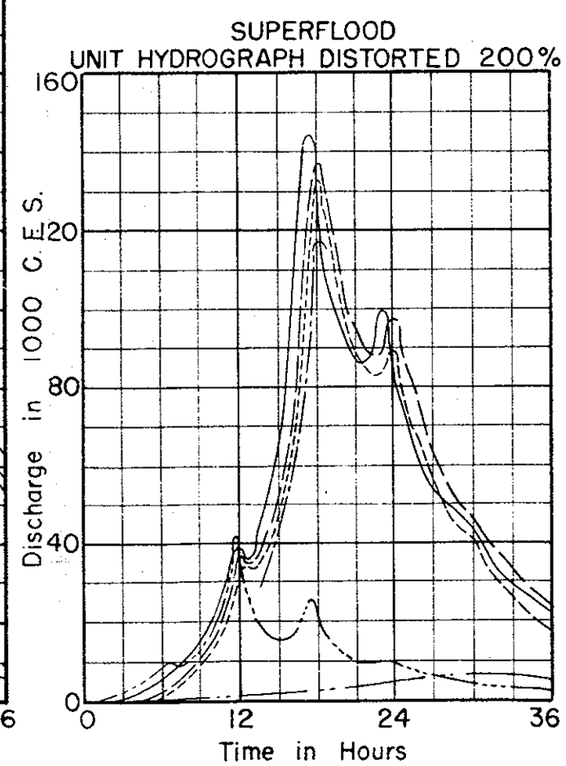
U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PRECIPITATION—RUN-OFF DATA WITHOUT SNOW									
Period (hours)	Net D.A. = 199 Sq. Mi.			Sunapee Lake D.A. = 46 Sq. Mi.			Total D.A = 245 Sq. Mi.		
	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)	Precipit. (in.)	Infiltra. (in.)	Run-off (in.)
0 - 6	0.10	0.10	.00	0.10	0.10	.00	0.10	0.10	.00
6 - 12	0.25	0.25	.00	0.25	0.25	.00	0.25	0.25	.00
12 - 18	2.00	0.30	1.70	2.00	0.30	1.70	2.00	0.30	1.70
18 - 24	9.10	0.30	8.80	7.50	0.30	7.20	8.80	0.30	8.50
24 - 30	4.00	0.30	3.70	4.00	0.30	3.70	4.00	0.30	3.70
30 - 36	1.10	0.30	0.80	1.10	0.30	0.80	1.10	0.30	0.80
36 - 42	0.25	0.25	.00	0.25	0.25	.00	0.25	0.25	.00
42 - 48	0.10	0.10	.00	0.10	0.10	.00	0.10	0.10	.00
Totals	16.90	1.90	15.00	15.30	1.90	13.40	16.60	1.90	14.70









LEGEND:

- Natural hydrograph – Sunapee Lake.
- Sunapee Lake effluent routed to dam site.
- Natural hydrograph - net area 199 square miles.
- Total natural hydrograph at dam site.
- Inflow hydrograph.
- Spillway discharge.

CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

COMPUTED SPILLWAY FLOOD AND DISTORTED SUPERFLOODS

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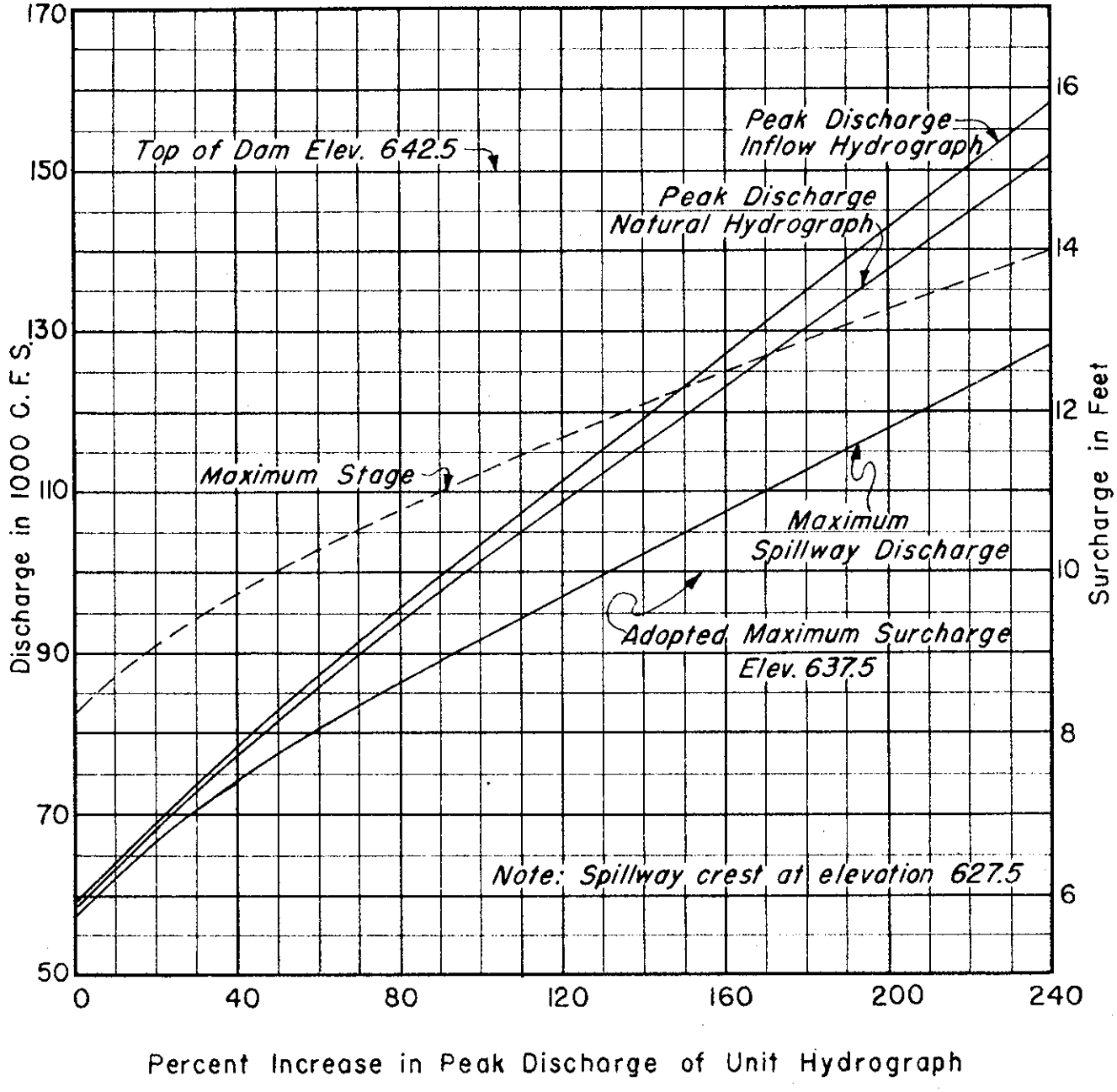
PLATE NO. 22



CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

SPILLWAY OVERLOAD CHARACTERISTICS

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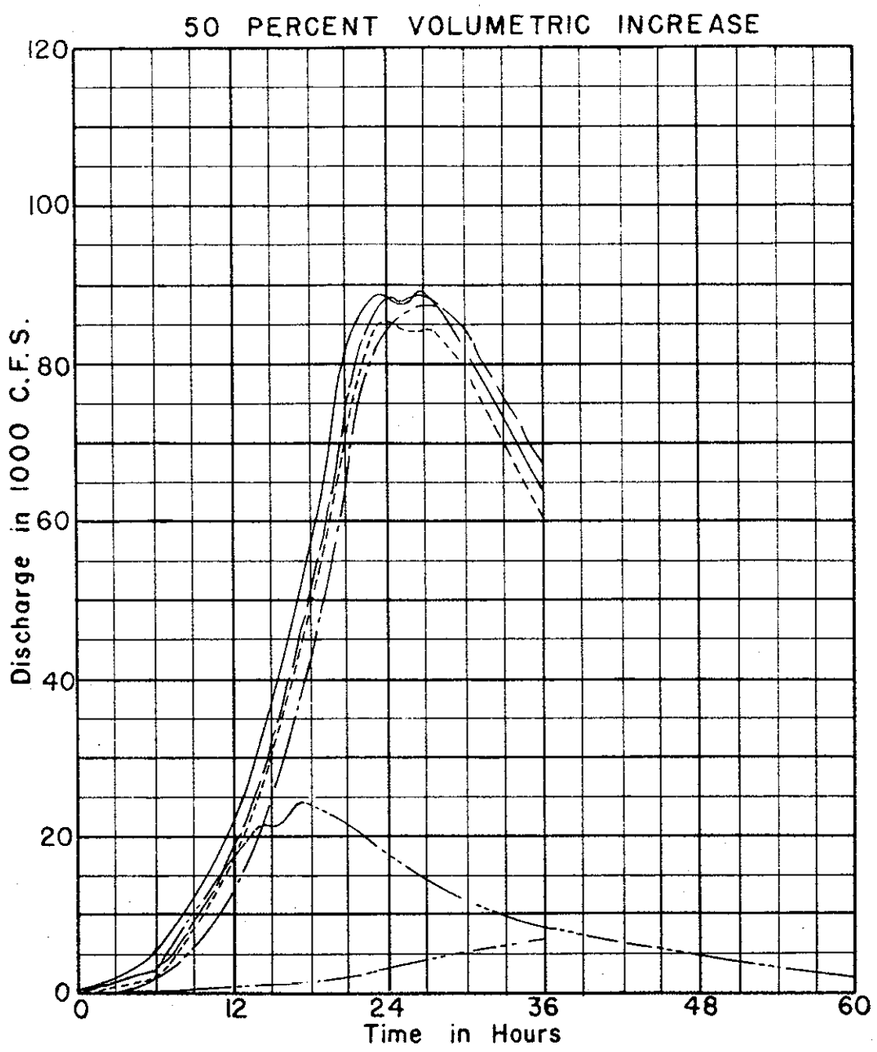
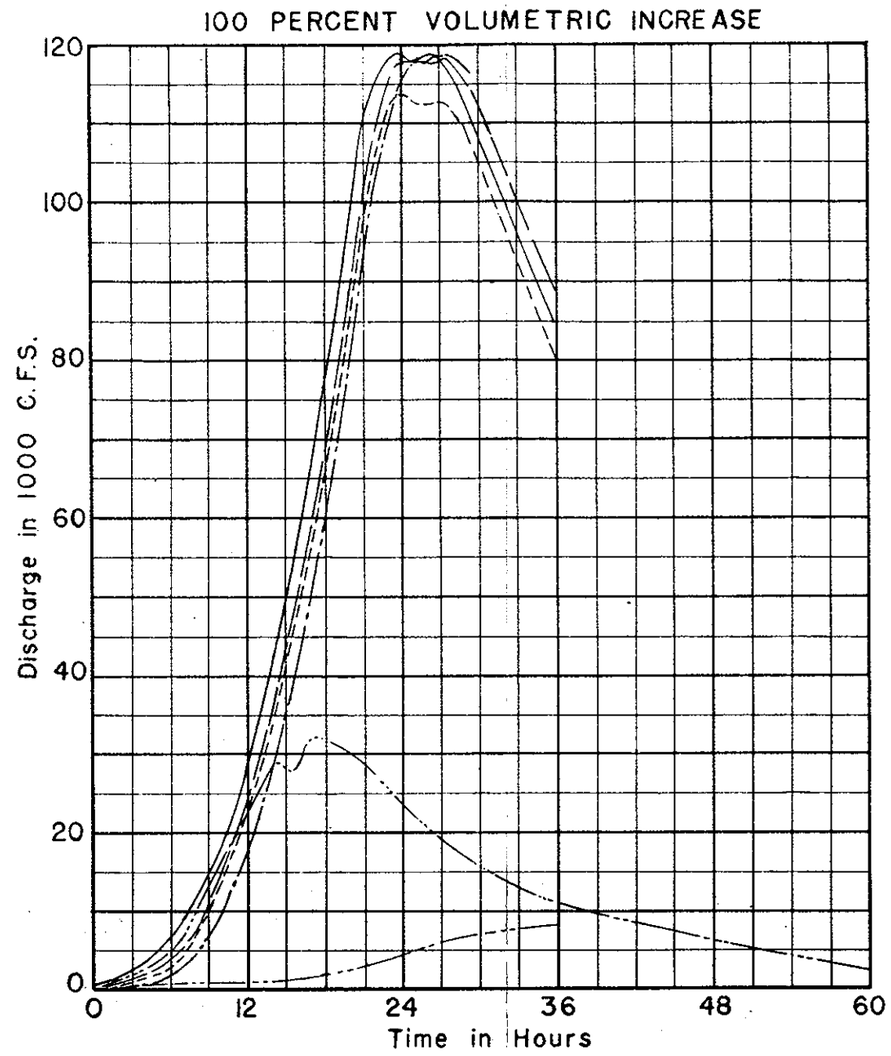
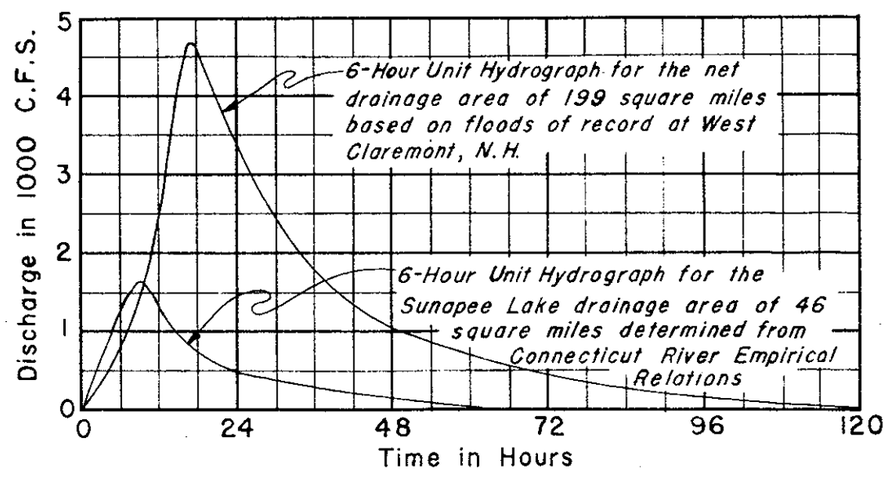






LEGEND:

- Natural hydrograph - Sunapee Lake
- Sunapee Lake effluent routed to dam site.
- Natural hydrograph - net area-199 sq. mi.
- Total natural hydrograph at damsite
- Inflow hydrograph
- Spillway discharge

Note: Rainfall excess 50 and 100 percent in excess of that for the computed spillway flood with the same proportional distribution.

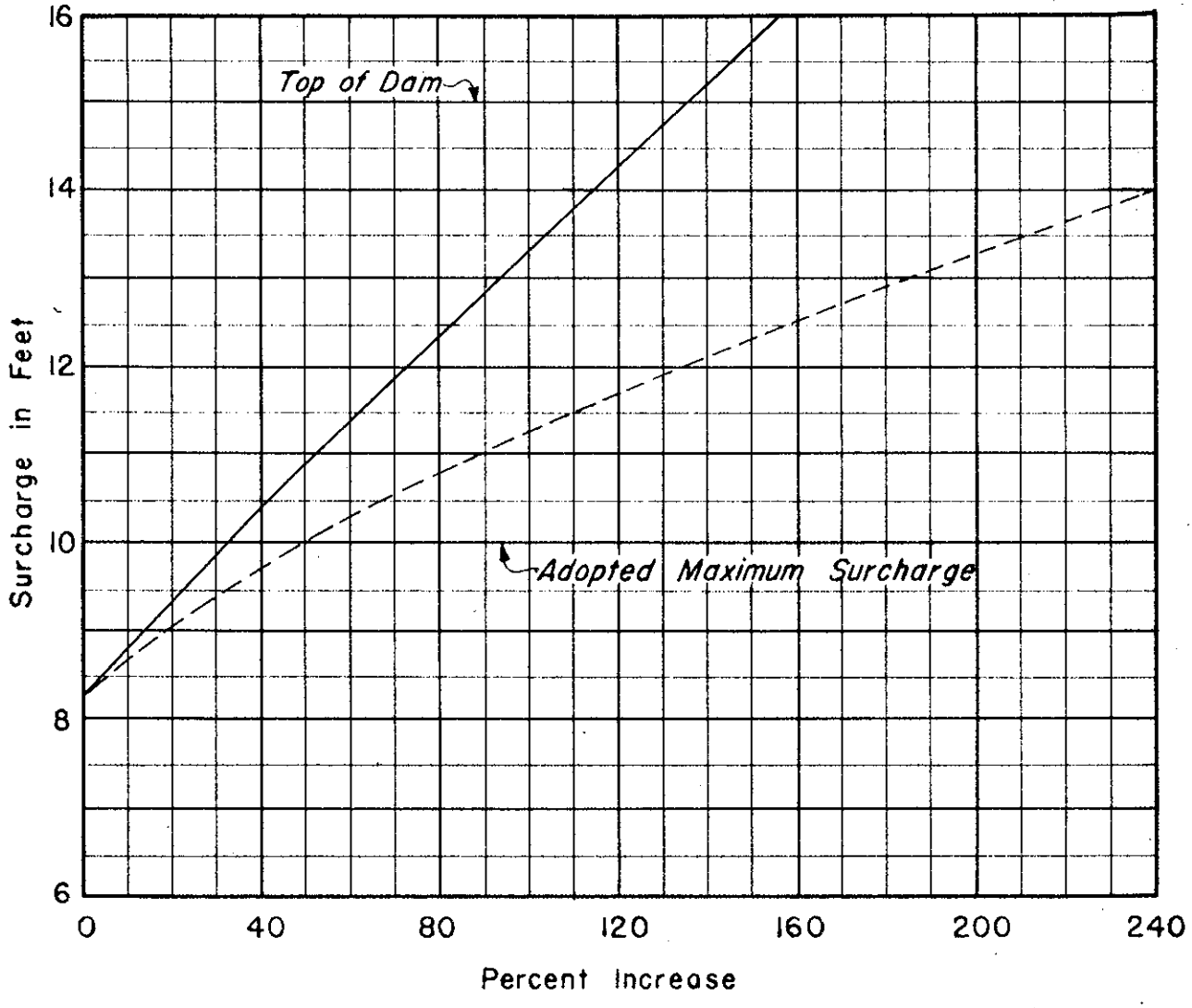
CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

VOLUMETRIC SUPERFLOODS

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

PLATE NO. 24



LEGEND

——— *Increase in volume of computed spillway flood (Unit hydrograph remains unchanged)*

— — — *Increase in peak of unit hydrograph (Volume remains unchanged)*

CONNECTICUT RIVER FLOOD CONTROL

CLAREMONT DAM

SPILLWAY REQUIREMENTS

U.S. ENGINEER OFFICE PROVIDENCE, R.I.