Records Holding Area

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Merrimack

MERRIMACK VALLEY FLOOD CONTROL

DEFINITE PROJECT REPORT

FOR

BLACKWATER RESERVOIR

BLACKWATER RIVER

CORPS OF ENGINEERS, U. S. ARMY

U.S. ENGINEER OFFICE BOSTON, MASS.

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September 15, 1939

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DEFINITE PROJECT REPORT

FOR

BLACKSTONE RESERVOIR

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WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
3RD FLOOR, PARK SQUARE BUILDING
BOSTON, MASS.

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR -
MERRIMACK RIVER BASIN FLOOD CONTROL

1. Project Authority. The Flood Control Act approved June 28, 1938, provides that, "The general comprehensive plan for flood control and other purposes (for the Merrimack River Basin), as approved by the Chief of Engineers pursuant to preliminary examinations and surveys authorized by the Act of June 22, 1936, is approved and the project for flood control in the Merrimack River Basin, as authorized by the Flood Control Act approved June 22, 1936, is modified to provide, in addition to the construction of a system of flood control reservoirs, related flood control works which may be found justified by the Chief of Engineers."

2. Previous Investigations. The results of an investigation of a system of flood control reservoirs and related flood control works for the Merrimack River Basin are contained in a preliminary examination and survey report authorized by the Flood Control Act approved June 22, 1936, and published as House Document, Public No. 689, 75th Congress, 3d Session. This report proposes several alternate combinations of reservoirs to serve as a general comprehensive plan of flood control in the Merrimack Basin, in all of which the Franklin Falls Reservoir now authorized for construction forms a component part. Other reservoirs proposed for selection as parts of these systems are located mainly in the Contoocook Valley. The Riverhill Reservoir, the largest of this group, was recommended for first priority to supplement Franklin Falls and has been selected by the Chief of Engineers as a definite project.

3. Practical objections have developed to the further prosecution of the Riverhill project. As explained in letter from this office to the Chief of Engineers, subject: "Selection of Definite Project - Merrimack River Flood Control," dated August 25, 1939, a further study is being made with a view to replacing Riverhill with an equivalent system of reservoirs in the Contoocook Valley. This study has progressed to the extent of positively indicating that any system of replacement should include the Blackwater Reservoir. The investigations have been reduced virtually to the consideration of two plans, a combination of Blackwater and the Contoocook River Flood Diversion Project, for which a favorable examination has been completed and was pre-

sented with letter to the Chief of Engineers cited above, and a second plan now being studied which was suggested by the Federal Power Commission. This latter plan comprises a system of ten small reservoirs in the Contoocook Valley, of which the Blackwater project would form a principal unit regardless of any modification which may be found desirable in the present study of this plan.

4. Location and Description of Area. Blackwater Reservoir is located on the Blackwater River in New Hampshire, 8.2 miles above the confluence with the Contoocook River and 115.8 miles above the mouth of the Merrimack River, of which the Contoocook is a tributary. The reservoir lies within the towns of Webster and Salisbury in the county of Merrimack, the dam being situated just above the village of Swetts Mills in Webster, 12.5 miles by highway northwest of Concord, N. H. The reservoir, which controls a drainage area of 127.5 square miles, has an area at spillway lip (El. 566) of 3,140 acres and a flood control storage capacity of 46,000 acre-feet, which is equivalent to 6.8 inches of run-off. The reservoir area is composed of approximately 12 per cent cultivated land, 9 per cent pasture land, 74 per cent wooded land, and 5 per cent water surface. No railroads or villages are involved and settlement and development in the region are sparse.

5. The Blackwater Reservoir, in conjunction with the Franklin Falls Reservoir now under construction and the proposed Contoocook River Flood Diversion Project, for which a preliminary definite project report was submitted to the Chief of Engineers with letter dated September 16, 1939, will form a coordinated system of flood control reservoirs in the Merrimack Basin approaching in both cost and predicted benefits the presently selected Franklin Falls and Riverhill Reservoirs.

6. Definite Project Plan. In view of the value of the Blackwater site for future combined storage and power development (see Appendix E), it is proposed to construct the Blackwater Dam initially for flood control, with provisions to facilitate future alteration for a multi-purpose development. The estimated additional cost of these provisions is $206,000.

7. Description of Structures. The proposed initial flood control development of the Blackwater Dam consists of a concrete spillway, a concrete non-overflow section, and an earth fill retaining section (see Plates VI, VII, and VIII). The concrete spillway is a wide-base, gravity-type Ogee section having a crest length of 185 feet and a maximum height of 56 feet. The concrete non-overflow section is adjacent to the spillway and consists of a buttressed section 60 feet long containing provisions for a future penstock intake and for future flood control outlet gates and a wide-base gravity section 140 feet long connecting with the earth embankment. The embankment is a semi-wide-base structure having a length of 770 feet and a maximum height of 60 feet. It is constructed of rolled earth fill with a central impervious core and is protected by an upstream rock shell and downstream rock-filled drainage toe. All

masonry structures and the impervious core and drainage toe of the embankment are placed on bedrock, which generally is available over the dam site within depths of 0 to 15 feet from the present ground surface. In addition to the main dam, one dike having a length of 1,200 feet and a maximum height of 34 feet is required for the flood control reservoir.

8. Hydrology and Hydraulics. Operating under the maximum design surcharge of 14 feet, the spillway will pass a flow of 36,000 second-feet, which is the outflow derived from routing the maximum possible flood through the reservoir. The peak inflow of this flood is 48,000 second-feet, which is equivalent to a run-off of 377 c.f.s. per square mile over the 127.5 square mile tributary drainage area and which gives a coefficient of 4,260 for "C" in the formula $Q = C\sqrt{A}$.

9. The initial flood control outlet is a single ungated square opening, 5 x 7 in cross-section, located in the gravity spillway. This outlet will discharge a maximum flow of 1,500 c.f.s. with the reservoir full to spillway lip. The capacity of the reservoir to spillway crest and the capacity of the outlet have been selected to provide control of a reservoir design flood derived from the maximum storm recorded in the New England area. The outlet will discharge uncontrolled into the natural rock channel of the river in remote location with respect to the earth embankment. A more complete description of the hydrologic and hydraulic design of this project, with supporting data, is contained in Appendices A and B herewith.

10. Cost Estimates. The estimated first cost of this project for flood control, with provision for future conservation and power development, is summarized below. Detailed cost estimates are contained in Appendix F.

Land and Relocation Costs	
Land, buildings and rights-of-way	$ 241,000
Highway relocation	130,300
Cemetery relocation	64,800
Utility relocation	20,300 456,400
Construction Costs	
Dam, dikes and reservoir clearing	818,600
Total Estimated Cost	$1,275,000

11. Economic Study. The results of an economic study of this project are contained in the tabulation following.

ECONOMIC ANALYSIS - BLACKWATER RESERVOIR

	First Cost	Annual Cost	Annual Benefits			Ratio, Annual Benefits to Costs
			Flood Control	Power	Total	
Blackwater*	$ 1,275,000	$ 62,700***	$140,000	$ —	$ 140,000	2.23***
		45,700****				3.06****
Blackwater**	3,730,000	207,300	140,000	250,500	390,500	1.89
Blackwater* and Franklin Falls	8,775,000	413,600***	662,000 763,700	—	763,700	1.85***
		396,600****				1.93****
Blackwater** and Franklin Falls	11,230,000	558,200	763,700	250,500	1,014,200	1.82
Blackwater,* Franklin Falls, and Contoocook River Flood Diversion Project	19,101,000	890,300***	907,500	—	907,500	1.02***
		873,300****				1.04****
Blackwater,** Franklin Falls, and Contoocook River Flood Diversion Project	21,556,000	1,034,900	907,500	250,500	1,158,000	1.12

* - Flood control project with dam, designed to facilitate future raising.

** - Multiple-purpose project for flood control, conservation, and power.

*** - Annual charges for Blackwater are based on $1,275,000 (first cost of project with provision for future raising).

**** - Annual charges for Blackwater are based on $965,000 (future flood control share of combined development cost prorated on basis of storage. See Appendix E).

12. Local Cooperation. No local cooperation is required for this project as authorized by the Flood Control Act of 1936 amended June 28, 1938. Consent by the state of New Hampshire to the construction of the Blackwater Reservoir is provided in "An act consenting to the acquisition of lands by the United States for flood control and navigation purposes" approved May 31, 1939.

13. Time Required for Construction. Provided operations are begun early in the construction season, about April 15th, the earth fill of the embankment can be completed by November 1 of the same calendar year and all items of work can be completed by the end of that calendar year.

14. Results Expected. The Blackwater Reservoir will control 17 per cent of the Contoocook watershed and approximately 2.6 per cent of the entire Merrimack drainage basin. The annual flood control benefits are estimated at $140,000, and stage reductions for a flood similar to that of March 1936 at Manchester, New Hampshire, will be about 1.1 feet. The Blackwater Reservoir, in conjunction with the Franklin Falls Reservoir and the Contoocook River Flood Diversion Project, will control 32.4 per cent of the total Merrimack Basin area and will afford benefits of $907,500 annually.

15. Recommendations. It is recommended that the Blackwater Reservoir be approved for immediate prosecution and that provisions be made in the initial dam to facilitate future alteration to include conservation storage and power development.

APPENDICIES

A-G

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR - MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX A

HYDROLOGY OF THE BLACKWATER RIVER DRAINAGE BASIN

Part I - The Spillway Design Flood

1. Reference. Reference is made to Engineer Bulletin, R. & H. No. 9, 1938, subject, "Spillway Capacities," which directs, in paragraph 19, that a hydrology report will be submitted to the Office of the Chief of Engineers for approval as the first step in the final design of a project.

2. Project Description. The Blackwater Dam site is located on the Blackwater River, a tributary of the Contoocook River. The dam is approximately 8-1/2 miles above the mouth of the river in the village of Swetts Mills in Webster Township, N.H. The reservoir controls a drainage area of 127.5 square miles, has an area at El. 586 of 3,140 acres, and a storage capacity of 46,000 acre-feet, equivalent to 6.8 inches run-off over the drainage area. The initial project, for flood control only, proposes use of the reservoir as a retarding basin with fixed outlet capacity and no gate control. One flood control outlet is provided in the base near the left end of the spillway section. The outlet has a discharge capacity of 1,800 c.f.s. with reservoir water surface at spillway lip. The concrete overflow spillway is 125 feet long, crest at El. 565, and maximum height of 65 feet.

3. Basin Characteristics. The drainage basin of the Blackwater River above the dam site is approximately 19 miles long, with a maximum width of about 12 miles. The river originates on comparatively steep mountain slopes with rapid run-off. The three headwater tributaries, comprising about one-half the total drainage area, combine in the two-mile reach above Potter Place, about 20 miles by river above the dam site. The total fall in the reach to the dam site is 100 feet, 40 feet of which are in the two-mile reach near West Salisbury; hence in the remaining 18 river miles the drop is about 60 feet, or about 3 feet per mile. The main valley is about 15 miles long and provides considerable valley storage, particularly in the reach below West Salisbury, that is reflected in the distribution values. Lakes, ponds, and swamps comprise about 8 square miles, or over 6% of the drainage area.

4. Stream Flow Data. A United States Geological Survey stream gaging station is located on the Blackwater River near Webster about 2 miles downstream from the dam site and has been in operation since

October 1934. It measures the flow from a drainage area of 130 square miles, only 1.5 square miles more than the drainage area at the proposed dam site. Records at this station have been used as the basis for stream flow data and studies of the distribution values. Staff gage readings and discharge measurements have been taken by this office at the Swetts Mills dam site to establish a tailwater rating curve and correlated to discharges recorded at the U.S. Geological Survey station. Discharge records based on one or two daily gage readings have been obtained by the U.S. Geological Survey further downstream near Contoocook (drainage area 134 square miles) from 1918-1920 and 1927-1934.

5. Precipitation Stations and Records. The only precipitation station in the Blackwater Basin is a non-recording station established by this office at South Danbury in January 1937. The records obtained at this station are considered exceptionally good for this type of station. The U. S. Weather Bureau has maintained for many years stations adjacent to the watershed. Stations used for this study are shown on Plate 13 and on Plate 14. The only recording rain gage applicable to the Blackwater River Basin is located at Concord, N.H., about 12 miles distance from the dam site. The mass curves of precipitation for the non-recording gages were drawn with and conforming to the Concord recording rainfall data.

6. Distribution Graph. The distribution values for the inflow hydrograph for Blackwater Reservoir were based on an analysis of the September 1938 flood. This flood had a peak value of 7,200 c.f.s. and is by far the maximum flood of record uninfluenced by snow run-off. The March 1936 flood, with a peak of 11,000 c.f.s., is the maximum of record but was primarily due to heavy snow melt; hence, uncertainties in required assumptions to utilize this flood for distribution values could not provide an acceptable check on the 1938 flood distribution values. A search for floods recorded at the present U.S. Geological Survey gaging station not affected by snow run-off gave 9 minor rises, with peak values less than 800 c.f.s. At the former U.S. Geological Survey station, with one or two daily readings, the maximum recorded discharge was 2,250 c.f.s., with possible backwater effect from the Contoocook River. A preliminary study of these minor floods showed peak distribution values appreciably lower than those from the 1938 flood due to the large effect of valley storage and regulation. The results could not be considered a check. The hydrograph recorded at the U.S. Geological Survey gage can be considered an outflow from the reservoir area without appreciable correction. In order to obtain an inflow hydrograph, this flood hydrograph was routed backwards through the valley storage of the reservoir site. The hydrographs are shown on Plate 15.

7. Plate 14 gives the mass curves of precipitation for the stations in and adjacent to the Blackwater Basin for the flood of September 1938. Six-hour rainfall values were obtained from these curves and distributed over the basin using Thiessen's weighting. The total weighted rainfall for the storm is 7.81 inches in 72 hours. The flood hydrograph, after deducting base flow, showed a run-off of 4.64 inches. Thus, the total infiltration and other losses amounted to 3.17 inches. The average rate of these losses was computed, based on weighted hourly rainfall and total losses, to be 0.087 inch per hour. The rainfall and run-off are shown in bi-hourly values on Plate 15. Six-hour distribution values were obtained for this inflow hydrograph, using six-hour rainfall values. The procedure and values used are shown on Plate 16. The reconstructed hydrograph, using the derived distribution values, shows a satisfactory check with the original hydrograph. The unit hydrograph, based on one inch of run-off occurring in a period of six hours, is shown on Plate 17.

8. The following terms are used, as defined in Engineer Bulletin, R. & H. No. 9, 1938: (a) Reservoir Design Flood; (b) Computed Spillway Flood; (c) Spillway Design Flood; (d) Freeboard; (e) Freeboard Storage; (f) Surcharge; (g) Surcharge Storage; (h) Wave Height; (i) Wind Setup.

9. Maximum Storm. The rainfall data for determining the maximum storm has been obtained from values furnished the Providence Office by the Hydro-Meteorological Section of the U. S. Weather Bureau. The data are shown in Plate 18. Comparison was made of the 24-hour and 48-hour depth-area curves from this storm with those for the total September 1932 and October 1903 storms and the 48-hour envelope curves developed by the Pittsburgh District Office, and both were found to give materially higher values of rainfall for a 127.5 square mile drainage area. Detailed study for this size drainage area of maximum storm data based on actual maximum storms of record (comparable to that obtained for the Franklin Falls project) is not available; hence, no absolute comparison can be made of the relative flood magnitude of summer and of spring storms with snow run-off. However, it is believed that for the small drainage area of the Blackwater River the much higher intensity of summer storms will prove to give appreciably greater peak values.

10. Computed Spillway Flood. The computed spillway flood was based on the derived distribution values and on the rainfall curves shown on Plate 18 and is shown on Plates 19 and 20. This is a summer storm and consequently an assumed minimum infiltration rate of 0.085 inch per hour, or 0.5 inch per six-hour period was adopted. This is less than the aver-

age rate of 0.087 inch per hour determined from the September 1938 flood, where conditions of excessive rainfall during July and the three weeks in September prior to the flood were productive of minimum infiltration rates. A base flow of 2 c.f.s. per square mile was added to the flow run-off. Data pertaining to this flood are briefly summarized as follows:

Rainfall	- 19.4 inches in 48 hours
Run-off	- 15.8 inches
Volume	- 110,600 acre-feet (including base flow)
Peak inflow	- 38,000 c.f.s.
Peak outflow	- 23,500 c.f.s.
Maximum pool elevation	- 576.3

Determination of Spillway Design Flood

11. Reservoir Operation Assumptions. It is assumed that the reservoir will be filled to normal maximum pool elevation of 566 feet M.S.L., which is the crest of spillway, at the beginning of the spillway design flood. The conduits are assumed to be inoperative.

12. Spillway Rating Curve. The spillway rating curve (Plate 21) was computed by the weir formula $Q = CLH^{3/2}$, where values of "C" for an unsubmerged Ogee section were taken from 3.3 to 3.8 at maximum head.

13. Method of Routing. As the computed spillway flood was based on distribution values for inflow to the reservoir, the flood was routed through the reservoir using the gross storage. (Reference is made to Appendix F of the "Survey Report for Flood Control, Merrimack River," dated April 1, 1938, for a detailed discussion of the reservoir routing used by the Boston Office.)

14. Spillway Design Flood. The computed spillway flood was routed through the reservoir to obtain the reservoir discharge and the maximum water surface elevation. The inflow ordinates of the computed spillway flood were then increased 50 and 100 per cent and similarly routed through the reservoir. The data derived from these three routings are shown graphically on Plate 22, where the per cent of computed spillway flood is plotted, (a) against the pool elevation in feet above mean sea level, and (b) against the peak inflows and outflows. After carefully considering all the factors itemized in the Engineer Bulletin, R. & H. No. 9, 1936, subject: "Spillway Capacities," paragraph 11, it was decided to adopt, as the "Spillway Design Flood" for the Blackwater Dam, the computed spillway flood plus a factor of safety of 50 per cent. The resulting spillway design flood is shown on Plate 23.

15. Discussion of Factor of Safety. In selecting 50 per cent as the factor of safety to be applied to the computed spillway flood, the following items, as enumerated in the Engineer Bulletin referred to in preceding paragraph, were considered:

a. The long-time rainfall records are too few to adequately cover all large storms of record in this district. Results of the storm studies now being made by this office, and other data as outlined in paragraph 9 above, show that the spillway design storm used gives rainfall values materially in excess of the maximum storms experienced. The design storm, based on data available in this office, is believed to give maximum rainfall values.

b. The maximum rainfall values shown in the depth-area curves on Plate 18 for 127.5 square miles are 1.43 times those for a like area in the September 1938 storm and exceed by a greater proportion the rainfall values for smaller drainage areas. The maximum point rainfall values available in this office were obtained from unofficial records. These values are 9.5 inches in about two hours at Peterboro, N.H. during the September 1938 storm and 11 inches in about two hours obtained during a cloudburst August 1939 at Baldwin, Maine. These values are over 50 per cent less than those shown for 3-hour rainfall on a one-square-mile drainage area. Hence, rainfall values given on Plate 18 are greater than those recorded in information available in this office. There appears to be little possibility that they will be exceeded.

c. The flood of September 1938 makes available an accurate determination of discharge quantities and reasonably accurate rainfall data. This is the only summer flood suitable for study, and with the excessive rainfall prior to the flood, should give values of infiltration closely approaching the minimum. The analysis of the September 1938 flood (Plate 15) indicated a rate of infiltration of 0.087 inch per hour. A lower value of 0.5 inch per 6-hour period (0.083 inch per hour) was used in the computed spillway flood. Expressed in terms of per cent run-off, this is equivalent to 88 per cent run-off for the maximum 24-hour precipitation.

d. The unit hydrograph (Plate 17) and distribution graph (Plate 15) are based on an analysis of the September 1938 flood, the second largest flood of record. The computed spillway flood peak value is approximately 4-1/2 times that of the 1938 flood. However, the surcharge storage of 50,000 acre-feet

available for the spillway design flood, with total volume of 165,000 acre-feet, is believed to minimize the inaccuracies inherent in the determination of the distribution values and the extrapolation of these values to a flood with peak value about 7 times that of the 1939 flood.

e. Errors in routing the design flood through the reservoir because of inaccuracies of assumed storage volume, backwater curves, and time of water travel is believed to be negligible. As the assumption is made that the reservoir is full at the beginning of the flood, the time of water travel is practically instantaneous through the reservoir. The spillway flood is computed as an inflow hydrograph and consequently consideration of the effect of valley storage in the reservoir was not required. The capacity curve of the Blackwater Reservoir is based on a topographic survey of the reservoir from which the values used for surcharge storage are obtained. There should be no appreciable error in the storage capacity curves or in the resulting reduction to the inflow peak obtained by routing the spillway flood through the surcharge storage.

f. Whether or not the outlet conduits are gated does not affect the criterion used, namely that during the duration of the spillway flood the outlet is assumed inoperative. Should the outlet actually be used for discharges during the spillway flood, the peak surcharge would be only slightly reduced. There is the possibility that the reservoir may be developed for power in the future. If this is done, the present proposal is to raise the crest of spillway to El. 584 and lengthen the spillway in order to reduce the surcharge. This will not change the basic spillway design storm or conditions, except to provide additional surcharge storage for a given increment of spillway surcharge.

g. The spillway is a straight overflow Ogee section. The spillway discharge rating has been computed with conservative values of "C" and it is believed that the spillway discharge capacity will actually exceed the computed values.

h. The freeboard storage in the Blackwater Reservoir is a considerable item. Between El. 579.8 and top of dam at El. 585 there are 22,500 acre-feet of storage, equivalent to 3.5 inches. There is a definite factor of safety against overtopping of the dam that may be attributed to this freeboard storage and spillway capacity, requiring a flood about 2.3 times the computed spillway flood to overtop the dam.

16. Summary. In view of the items discussed in the preceding paragraphs, it is believed that a 50 per cent factor of safety applied to the computed spillway flood is adequate. The hydrograph of this flood is shown on Plate 33 with the outflow-stage hydrographs and reservoir elevations. Data concerning this flood are summarized as follows:

Selected Spillway Design Flood
(Computed Spillway Flood Plus 50 Per Cent)

Volume = 164,000 acre-feet (including base flow)

= 24.3 inches of run-off from a 48-hour period of rainfall

Peak inflow = 48,400 c.f.s.

Peak outflow = 35,600 c.f.s.

Maximum pool elevation 979.8 ft. above m.s.l.

Freeboard 3.2 ft.

Part II - Reservoir Design Flood

17. Maximum reservoir capacity is governed by the physical limitations of the dam site and by the size of the maximum probable flood. The former is determinable from the field surveys, the latter is not definitely determinable because of limited length of adequate discharge records. Another factor in the physical limitation to storage is the outlet discharge, governed by channel capacity and related to the storage proposed and reservoir design storm used. It is desirable to discharge from the outlets a flow not exceeding channel capacity or limiting the flow to that value which will not cause flooding on the tributary. This item of channel capacity is not important on the Blackwater River from the standpoint of flood damage in the reach from the dam to the Contoocook River. The greater the storage provided for the given storm, the smaller the outlet discharge and the greater the flood reduction obtained downstream. However, there is a practical limitation to the reduction of outlet discharge in that a flood control reservoir should be emptied in a reasonable time to provide for the possible condition illustrated by the 1936 flood where two major storms produced peak floods within a week of each other.

18. Related to all of the above factors is the economic consideration limiting the cost of the storage capacity to that which will give the greatest ratio of benefits to costs.

19. The reservoir design flood formerly used was based on economic consideration wherein it appeared desirable to limit the size of the reservoir to control a flood produced by a rainfall of about 100-year frequency, and also to empty the reservoir in a reasonable length of time. To arrive at such a storm, long-time rainfall records at Concord were studied. It was found from these records that a 100-year rainfall of 3-days' duration amounted to about 8 inches. With this storm a high run-off factor of 90 per cent was applied. In order to justify this high run-off factor, a 3-day storm of 1-1/2 inches of rainfall per day was added prior to the 100-year 3-day storm. This gave a flood volume that, in its effect on reservoir capacities, was about equivalent to the 1936 flood, the maximum flood of record. The flood obtained from these assumptions, however, must be considered as one of less frequent occurrence than once in 100 years because of the assumptions made of the 3-day prior rainfall and the high run-off coefficient. This flood, when routed through the reservoir with a maximum outlet discharge of about 1,800 c.f.s., gave a spillway lip or maximum pool elevation of 566 feet.

20. An approach to the maximum probable flood may be had by consideration of the maximum available storm of record. Recent study of recorded maximum storms show that apparently the greatest storm of record in New England was that of September 1938, with principal center at Westerly, Rhode Island. This storm compares in magnitude with others outside of New England that are considered as possible of occurrence in New England. This office has detailed information on the 1938 storm, and it is considered as a rational basis for computation of a reservoir design flood approaching the maximum probable flood. Utilizing this flood with the most severe condition of run-off, comparable with that obtained in the 1938 flood, gives a severe criterion for selection of reservoir capacity. Plate 23 shows the depth-duration curves of the 1938 storm used for deriving the values of rainfall, while Plate 23 shows the constructed inflow hydrograph and the resulting outflow-stage hydrographs.

21. This storm produces an extremely high peak with moderate volume. When routed through the reservoir, the assigned storage capacity was found to be sufficient to control the flood, except for a moderate spillway outflow of 1,200 c.f.s. The rare frequency when this small flow in excess of the conduit capacity will occur is considered a negligible factor. Hence, it is believed that the flood based on the 1938 storm is a reasonable criterion for a reservoir design flood based on summer rainfall conditions.

22. The March 1936 flood, in most cases on the Merrimack Basin, exceeded in peak value, and definitely in volume, any flood of record. Since, in reservoir flood design, volume is of primary importance, reservoir design in the Merrimack Basin must recognize the spring flood as the possible governing criterion. Storage provided in the Blackwater Reservoir is found to be ample to control the 1936 flood with the proposed outlet capacity. (See Plate 24.)

23. Study of all the factors involved in consideration of the control of the Blackwater River floods led to the choice of 46,000 acre-feet of flood control storage. The possibility that there may be some excess flood control storage in the Blackwater Reservoir should be considered a desirable condition in connection with the comprehensive scheme of flood control on the Merrimack to augment the limited storage available on the Penigewasset River and hence increase the effectiveness of the combination.

APPENDIX B

HYDRAULICS

1. The hydraulic design of the Blackwater Flood Control Dam presents no unusual features. The flood control outlet is a short, rectangular passage 5'x7', through the concrete spillway section of the dam. The outlet is ungated and provided with a bell-mouth entrance and trash bars. Some modification of the outlet area for the final design may be made to insure the required discharge capacity of 1,500 c.f.s. with pool at El. 566. No stilling basin is required, the outlet discharging into a rock gorge entirely separate from the earth section of the dam. An Ogee free overfall concrete spillway 185 feet long is provided, the capacity being readily computed from the weir formula (see Plate 21). The structure is founded on rock with a curved bucket for the high portion of the spillway to deflect the overflow parallel to the stream bed. The gorge below the spillway is narrow, with steep fall, and will pass the spillway design outflow peak without submerging the spillway crest. The flood reductions at the dam site were obtained by reservoir routing, using inflow hydrographs. The results are shown for the March 1936 flood, the flood based on the September 1932 storm, and the spillway design flood, on Plates 24, 29, and 33, respectively.

2. Reductions to the flood at the dam site were carried downstream to the damage centers through Haverhill on the Merrimack River. The March 1936 flood, surpassing all other floods of record in the Merrimack Basin in magnitude and general extent, provides an excellent measure of the probable effectiveness of the reservoir. Downstream reductions were computed for the Blackwater Reservoir alone and in combination with the Franklin Falls Reservoir, and also in combination with the Franklin Falls Reservoir and the Contoocook River Flood Diversion Project. The Blackwater Reservoir, with 6.5 inches of storage, is entirely adequate for all minor floods or spring freshets. Its maximum effectiveness in reduction of large floods may best be gaged by its effect on the 1936 flood. The 1936 flood, as recorded at the U. S. Geological Survey gage near Webster, was routed through the reservoir. Plate 24 shows inflow, outflow, and stage hydrographs for this flood.

Pertinent data concerning this flood are as follows:

1936 peak discharge	11,050 c.f.s.
Reduced reservoir peak discharge . .	1,800 c.f.s.
Maximum pool elevation	562.0

3. The effect of the Blackwater Reservoir in reducing the 1936 flood at two of the downstream damage centers, Manchester, N. H. and Lowell, Mass., on the Merrimack River, is shown by the hydrographs on Plates 25 and 26. The same plates also show the discharge reduction credited to the Franklin Falls Reservoir (now under construction) and the combination of the Franklin Falls and Blackwater Reservoirs. It shows at these two points that Blackwater Reservoir in combination with Franklin Falls adds about 5,000 c.f.s. to the peak reduction for the 1936 flood.

4. Plate 27 shows the effect of distance on the discharge reductions as applied to the flood of March 1936. These curves are based on reach-routing computations and are useful in determining discharge reductions at intermediate damage centers.

DEFINITE PROJECT REPORT FOR BLACKSTONE RESERVOIR - BLACKSTONE RIVER MAIN FLOOD CONTROL

APPENDIX C

GEOLOGY AND SOIL DATA

1. Foundation of Dam Site. The Blackstone dam site is located at a point where the river has incised a narrow bedrock gorge more than twenty feet deep immediately below its winding course across an old glacial lake flat. Adjoining the narrow gorge on the right is a secondary valley of much broader expanse but shallower depth, the bottom of which has been eroded to bedrock by the occasional overflow of flood discharges into this valley from the main river above the dam site. Bedrock is either exposed or accessible over the entire dam site at depths rarely exceeding 15 feet. The rock structure is generally a coarsely crystalline granite, with some phases of gneiss, and for the most part is much fractured. This latter fact will necessitate an extensive and well-planned grouting program under the entire dam to avoid serious leakage from a future conservation pool. For structural purposes the rock is entirely satisfactory with a minimum of grouting. The dam-site overburden is of two general types, a well-graded fine to coarse sand with a trace of silt and some gravel, and a more uniform fine to medium sand with a trace of silt. Coefficients of permeability of these materials range from 5 to 50×10^{-4}. The dikes will involve no foundation or borrow difficulties for either the initial or ultimate reservoir development.

2. Dam-Site Exploration. The dam site has been explored with a total of 19 drill holes and 51 test pits (see Plate IV). Logs of the drill holes are shown on Plate V, and typical grain-size curves of the foundation overburden on Plate XX. No additional drill holes and test pits are required in the foundation area.

3. Borrow Materials. Ample borrow materials for both the core and random fill sections of the embankment are available in close proximity to the dam site (see Plate XXI).

4. The core material is a well-graded, cohesive material containing approximately 10 per cent clay and approximately 2 per cent solids larger than 1/4 inch up to boulders 2 feet in mean diameter. This material has a coefficient of internal friction of 27 degrees, a cohesion of 0.10 ton/sq. ft., and a coefficient of permeability of 2×10^{-7} cm/sec. It occurs in nature at an average dry weight of 124 lbs./cu. ft. with an average water content of 10 per cent and can be compacted, as deter-

mined from results of actual compaction tests with tractor and roller, to an average dry weight of 120 lbs. with an optimum water content of about 13 per cent.

5. The random fill material is a well-graded, cohesionless, silty and gravelly sand containing approximately 20 per cent silt and approximately 15 per cent to 20 per cent of solids larger than 1/4 inch up to boulders 5 feet in mean diameter. The material has an angle of internal friction of 36 degrees and a coefficient of permeability of 1×10^{-4} cm./sec. It occurs in nature at an average dry weight of 119 lbs./cu. ft., excluding particles larger than 1/4 inch and with an average water content of 5 per cent. It can be compacted in 12-inch layers, with normal application of the tractor and roller, to a dry weight of 122 lbs./cu. ft. with an optimum water content of 9 to 10 per cent. A dry weight of 122 lbs./cu. ft. represents a degree of compaction for this material of about 75 per cent.

6. No gravel borrow areas suitable for the production of concrete aggregates have been found in the Blackwater valley. The nearest deposits providing a suitable source for these materials are located along the Warner River and will require a haul of more than four miles. There are certain localized deposits of sand and gravel within a radius of about two miles of the Blackwater Dam which will supply the requirements for run-of-bank filter material. These deposits are generally low in gravel content, averaging 15 to 20 per cent.

PRELIMINARY PROJECT REPORT FOR BLACKWATER RESERVOIR - MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX B

SELECTION OF STRUCTURES AND DESIGN

1. Selection of Structures. Because of the general availability of bedrock throughout the entire area of the dam site, numerous arrangements of the structures of the dam are possible. Of the five alternate layouts of the Blackwater Dam studied by this office, the general plan of the dam proposed in this report (see Plate VI) presents the most practical and economical arrangement with both present and future developments in view. The spillway and outlet structures are located in the rock gorge of the river remote from the earth embankment and therefore do not require either approach and discharge channels or any form of stilling basin. The future penstock intake and flood control outlet structures are in immediate adjacency and can be housed and serviced as a unit. Excellent foundation conditions and borrow materials are available for the construction of an embankment to form the main retaining section of the dam which has been found to be considerably more economical than a concrete retaining section.

2. Structure Design. The masonry sections of the initial dam are ultimate width structures proportioned to withstand the forces applied to the future completed dam. The stability analysis is based on a water level in the reservoir equivalent to the extreme high water resulting from the spillway design flood, and an uplift pressure over 50 per cent of the area of any section equal to 100 per cent of the headwater pressure at the upstream face tapering to 100 per cent of the tailwater pressure at the downstream face. Under these conditions, the resultant is held within the middle third of the base and the sliding factor does not exceed 0.65. Maximum base pressures are approximately 5 tons/sq.ft. and the inclined maximum stress in the concrete at the toe is less than 100 lbs./sq.in. The maximum stress in the buttresses of the intake structure does not exceed 400 lbs./sq.in.

3. The openings provided in the initial dam for future penstock connection and relocation of the flood control outlets are closed with concrete bulkheads. Recesses are provided for future installation of caterpillar self-closing type service gates and appurtenant guide and sealing parts and for carwheel self-closing type emergency gates and appurtenant parts. Recesses are provided in the flood control conduits for future installation of cast-iron liners for protection against cavitation. Air vents are provided immediately downstream from

all future service gates. The bedrock foundation will be grouted throughout the entire length of the dam to reduce to an economical minimum the leakage from a future conservation pool. Pending further study of this problem, it is planned to grout the foundation from a minimum depth of 20 feet to a maximum of 50 feet with holes averaging 4 feet center to center.

4. An analysis of the upstream slope of the earth embankment, assuming sudden drawdown of a full pool, indicates that the minimum stability ratio of this slope is 1.40. The central impervious core of the embankment will be founded on bedrock. The latter will be grouted and capped at the surface to provide a satisfactory contact for the core material. Because of the high impermeability of the core material and the treatment of the rock foundation, no seepage problem exists requiring more than a nominal downstream drainage toe.

5. Diversion of the Blackwater River during the construction of the masonry structures in the river gorge can be effected by cofferdamming the full width of the gorge above the dam and passing the flow down the adjacent secondary valley. The diverted flow will return to the river about 2,000 feet downstream from the dam. This plan permits an unobstructed working area in the narrow stream bed and should not delay construction of the embankment, as preparatory excavation and grouting work and the placement of some fill in the embankment area adjacent to the right abutment can be carried on during diversion. The excavation of a small canal is required for the diversion, as shown on Plate IV. In addition, the placement of a small diversion dike and the enlargement of a highway culvert are required near the return of the diversion course to the river. Following completion of the masonry structures to El. 535, the cofferdam will be removed and the flow passed through the flood control outlets in the dam. This program provides a minimum capacity of 2,000 second-feet for handling the river flows.

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR - MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX B

POWER STUDY

1. The comparatively inexpensive storage obtainable at the Blackwater Reservoir and the existence of 209 feet of developed head below the site on the Contoocook and the Merrimack Rivers render it a desirable power storage site. Studies have therefore been undertaken to investigate the feasibility of obtaining storage capacity over and above that required for flood control and also of possible power development at the reservoir site, where power head of about 200 feet can be developed.

2. By raising the spillway crest elevation 18 feet above that selected for the flood control structure (El. 566 to El. 584 above mean sea level) a total storage capacity of 115,000 acre-feet (16.9") will be created in a multiple-purpose reservoir. Providing the requisite flood control storage of 46,000 acre-feet (6.8") between El. 573 and El. 584, there will remain 69,000 acre-feet (10.1") of storage capacity below El. 573 for use in the interests of power and conservation. Studies indicate that the above power storage capacity is the most economical, resulting in the lowest unit cost of storage benefits.

3. Studies made for the period of 1924-1937, which includes the unusually dry season of 1930-1931, show that the existing power installations on the Merrimack River below Penacook, representing 165 feet of developed head*, would benefit from the increased low-water flow due to operation of Blackwater power storage to the extent of 6,500,000 kwh. With the reservoir operated for Manchester, the low-water flow at that point would be increased from 996 c.f.s. to about 1,300 c.f.s. (monthly mean), raising the prime peaking capacity of the existing installations by about 3,000 kw.

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* This head excludes the small plants on the Contoocook River at Penacook, which, with their existing generating facilities, would not benefit fully from the increased low flows.

4. The power development at the reservoir site involves a 10,000-foot penstock line from the dam to the power house site at Snyder's Mill, where a 10,000-kw. installation could be undertaken. At primary load factor of 20 per cent, the dependable capacity of such a plant would be 6,600 kw. and the average annual output 22,000,000 kwh.

5. Employing the power values as formulated by the Federal Power Commission, namely $11.50 per kw. of dependable capacity and 3.3 mills per kwh. of energy output, the annual power benefits obtainable would amount to $171,600 at the site and $78,900 at the existing downstream plants on the Merrimack River, or a total of $250,500.

6. Realization of the foregoing power benefits is contingent upon the increased power demand and upon cooperation of the benefiting downstream interests. It is contemplated, therefore, that only provisions for future incorporation of power are to be made in the design of the initial low dam intended for flood control alone.

7. Estimate of Costs and Benefits.

Storage Costs:

Flood control project (spillway crest at El. 556)	$ 1,069,000
Flood control project, designed to permit future raising	$ 1,275,000
Future raising of structures and reservoir	1,137,000
Total cost, multiple-purpose reservoir	$ 2,412,000

Allocation of Storage Costs:

	First Cost	Annual Cost
Total storage capacity - 115,000 acre-feet	$ 2,412,000	$ 114,300
Flood control - 46,000 acre-feet - 40%	965,000	45,700
Power - 69,000 acre-feet - 60%	$ 1,447,000	$ 68,600
10,000-kw. power plant, complete	1,318,000	93,000
Total cost, power development	$ 2,765,000	$ 161,600

Power Benefits:

Plant at site	$ 171,600
Downstream energy benefits	21,400
Downstream capacity benefits	57,500
Total Power Benefits	$ 250,500

Cost of Energy Output, Plant at Site:

a. With full participation by the benefiting downstream plants	3.8 mills per kwh.
b. With no participation by the benefiting downstream plants	7.4 mills per kwh.

Ratio, Power Benefits to Power Costs:

a. With full participation by the benefiting downstream plants	1.55
b. With no participation by the benefiting downstream plants	1.06

The allocation of costs between the flood control and power portions of the multiple-purpose reservoir in the foregoing summary has been made in proportion to the respective storage capacities reserved for the exclusive use of flood control and power in accordance with Circular Letter, Office, Chief of Engineers, R. & H. No. 43, 1939.

5. It is to be noted that the cost of modifying the flood control structure to permit future raising is $206,000. This added cost, although non-productive until the structures are raised and power facilities installed, nevertheless represents an investment, the interest charges on which are to be met. The total ultimate cost of power development, therefore, as given above, will be subject to an increase depending on the length of time elapsing before the ultimate multiple-purpose project is executed.

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR - MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX F

COST ESTIMATES

1. The estimated costs of the several alternate plans of development investigated for the Blackwater Reservoir are summarized as follows:

A.	Flood Control Alone (Spillway El. 566)	$1,069,000
B.	Flood Control, Wide Base Dam (Spillway El. 566)	$1,275,000
C.	Future Addition for Conservation (Spillway El. 584)	$1,137,000*
D.	Combined Flood Control and Conservation (Spillway El. 584) Items B and C	$2,412,000*

*Does not include cost of power development at the site.

2. The detailed estimate of cost of the Blackwater Reservoir constructed initially for flood control, with provision for the future addition of conservation storage and the development of power (Plan D as above), is itemized as follows:

Item	Quantity	Unit	Unit Cost	Cost	Total Cost
1. Reservoir Costs					
Land	3,500	acre	$ 22.00	$ 53,600	
Buildings		l.s.		65,000	
Cemeteries - Relocation	960	grave	50.00	48,000	
Power Privileges Destroyed		l.s.		10,000	
Telephone and Telegraph Lines - Relocation	4	mile	2,500.00	10,000	
Power Line - Relocation	2	mile	2,500.00	5,000	
Highway Relocation		l.s.		96,500	
Sub-Total Reservoir Costs				$338,100	$338,100
Engineering, Appraisals, Overhead & Contingencies (35%)					118,300
Total Reservoir Costs					$456,400

Item	Quantity	Unit	Unit Cost	Cost	Total Cost
II. Construction Costs					
(a) Dam, Spillway & Outlets					
Stream Diversion & Pumping		l.s.		$ 10,000	
Stripping Dam Site	19,300	c.y.	$ 0.40	$ 7,700	
Clearing & Grubbing	8	acres	150.00	1,200	
Common Excavation	29,100	c.y.	0.30	8,700	
Rock Excavation	11,500	c.y.	1.50	17,300	
Impervious Borrow	36,600	c.y.	0.43	16,200	
Random Fill Borrow	160,700	c.y.	0.35	56,200	
Structure Backfill-Un-compacted	2,500	c.y.	0.10	300	
Rolled Fill - Impervious	35,900	c.y.	0.10	3,600	
Rolled Fill - Random	168,300	c.y.	0.10	16,800	
Rock Fill	17,000	c.y.	0.50	8,500	
Sand for Filter	7,900	c.y.	1.00	7,900	
Sand & Gravel Backing	7,700	c.y.	1.25	9,600	
Top Soil	4,700	c.y.	1.00	4,700	
Drilling Holes for Grouting	10,900	l.f.	0.75	8,200	
Pressure Grouting	4,400	c.f.	1.00	4,400	
Line Drilling	2,500	s.f.	0.80	2,000	
Concrete - Intake Structure	3,620	c.y.	17.00	61,500	
" - Non-Overflow Spillway & Walls	19,430	c.y.	11.00	213,700	
Reinforcing Steel	217,000	lb.	0.05	10,900	
Structural Steel	61,300	lb.	0.08	4,900	
Electric System		l.s.		3,000	
Misc. Service Lines, Field Office, Service Roads		l.s.		20,000	
Seeding	2.92	acres	300.00	900	
Total Dam, Spillway & Outlets				$508,200	$ 508,200
(b) Dikes					
Clearing & Grubbing	2.2	acres	150.00	$ 300	
Stripping	8,100	c.y.	0.40	3,200	
Rolled Fill - Impervious	17,400	c.y.	0.60	10,400	
Rolled Fill - Random	40,100	c.y.	0.50	20,000	
Top Soil	3,500	c.y.	1.00	3,500	
Seeding	2.2	acres	300.00	700	
Total Dikes				$ 38,100	38,100
(c) Reservoir Clearing		l.s.		$ 60,000	60,000
Sub-Total Construction Cost					$ 606,300
Engineering, Inspection, Overhead and Contingencies (35%)					212,300
Total Construction Cost					$ 818,600
Total Estimated Cost Initial Dam					$1,275,000

COPY
(Original inclosures not attached.)

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR - MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX G

August 25, 1939

Subject: Selection of Definite Project - Merrimack River Flood Control

To: The Chief of Engineers, U. S. Army, Through the Division Engineer, North Atlantic Division, New York, N. Y.

1. The definite projects selected by the Chief of Engineers for the comprehensive flood control plan for the Merrimack River Basin are, at the present time, the Franklin Falls and Riverhill Reservoirs. Funds are available for and construction has been started on the Franklin Falls Reservoir. Active work on the Riverhill Project has been suspended since early in 1939.

2. At a series of five hearings held in the winter of 1938-1939 in connection with a preliminary examination of the Merrimack River, intense local opposition was evidenced to the construction of the Riverhill Reservoir. The expressions of local interests at these hearings and subsequent expressions during the preparation and passage of enabling legislation for acquisition of lands indicate that the state of New Hampshire will withhold consent to the acquisition of lands for the Riverhill Reservoir until it can be definitely shown that there is no satisfactory substitute.

3. This circumstance has been kept in view during the studies being carried on in this office for a flood control report on the Merrimack River. The studies have revealed that comprehensive control of floods in the Merrimack River Basin cannot be obtained economically without providing a large degree of control of the Contoocook watershed, in which the Riverhill Reservoir is located.

4. The problem of a substitute for the Riverhill Reservoir, then, has resolved itself definitely into a substitute plan for the control of the Contoocook River. A system of small reservoirs in the Contoocook Basin was suggested by the Federal Power Commission in a letter to the Secretary of War dated May 8, 1939. The Commission estimated that the small reservoir system would have costs and benefits about equal to the Riverhill Reservoir. It is the opinion of this office that an estimate of cost of the Commission's plan, based on more complete field informa-

tion now being obtained, will exceed the cost of the Riverhill Project considerably. Meanwhile, however, the studies have revealed other possibilities for flood control in the Merrimack River Basin which appear to offer equivalent flood protection to that afforded by the Riverhill Reservoir and which appear to be preferable to the Riverhill Reservoir from the standpoint of total cost, cost of lands and rights-of-way, and the interests of local residents and agencies affected.

5. The substitute plan for Riverhill Reservoir consists of two units: First, Blackwater Reservoir Project, which was previously studied and considered as an alternate reservoir in House Document 659, 75th Congress, 3d Session, and second, the Contoocook Diversion Project. The Diversion Project was suggested as a possibility by the New Hampshire Water Resources Board, with the end in view that this plan, if found adequate and economically justified, would be preferable to the Riverhill Reservoir, in so far as local interests and state authorities were concerned, since it involves considerably less disruption of local affairs through the taking of lands and rights-of-way. It should be noted that the Blackwater Project is a common element of the Federal Power Commission plan and the plan proposed herein, as well as any other possible substitute system designed to replace the Riverhill Reservoir.

6. Sufficient field investigations and office studies have been made of this plan to establish the fact that the project will be economically justified and that it will give flood protection practically equivalent to that afforded by Riverhill. There are attached a sketch map and general data on the Diversion Project and comparative tabulations showing the costs, effectiveness and benefits of a combination of the Franklin Falls and Blackwater Reservoirs and the Contoocook Diversion Project against the combination of the Franklin Falls and Riverhill Reservoirs, which constitutes the selected comprehensive plan at the present time.

7. It will be noted that the Franklin Falls-Blackwater-Diversion Project combination can be built within the authorized limit of $21,000,000 as set up for a comprehensive plan in House Document 659 and approved by the Flood Control Act of June 28, 1938. Furthermore, construction costs and the cost of lands and rights-of-way fall within the proportions of $13,000,000 and $5,000,000 contemplated in the comprehensive plan in House Document 659; also, the costs are sufficiently below $21,000,000 to permit the inclusion, without exceeding the authorization limit, of penstocks or other similar power facilities where considered necessary.

8. In view of the facts that the costs and benefits of the proposed substitute plan are practically equivalent to the Franklin Falls-Riverhill plan, that enabling legislation for the Blackwater Reservoir has already been provided by the state of New Hampshire, and that local opposition to the taking of lands for the diversion scheme is not

likely, it is recommended that the Riverhill Reservoir Project be abandoned and that the Blackwater Reservoir and the Centecook Diversion Project be substituted therefor as part of the comprehensive plan for which the Chief of Engineers now has authority to select definite projects.

9. It is proposed to -

a. Submit a definite project report on Blackwater on September 15, 1939, at which time authority to proceed with the preparation of plans and specifications will be requested.

b. Submit a preliminary definite project report on the Diversion plan on September 15, 1939, at which time authority to proceed with the final exploration will be requested.

c. Submit a final definite project report on the Diversion plan along with results of a final analysis of the Federal Power Commission plan, on February 1, 1940, at which time authority to proceed with the preparation of plans and specifications for the Diversion plan will be requested.

d. Cooperate with representatives of the Federal Power Commission regarding installation of penstocks in the Diversion plan prior to submission under paragraph (c).

10. Approval of procedure outlined in paragraph 9 is requested at this time.

A. K. B. Lyman
Colonel, Corps of Engineers
District Engineer

4 Inclos.: (in triplicate)
Map of project
General data
Summary of costs and benefits
Analysis of flood control effectiveness

PLATES

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

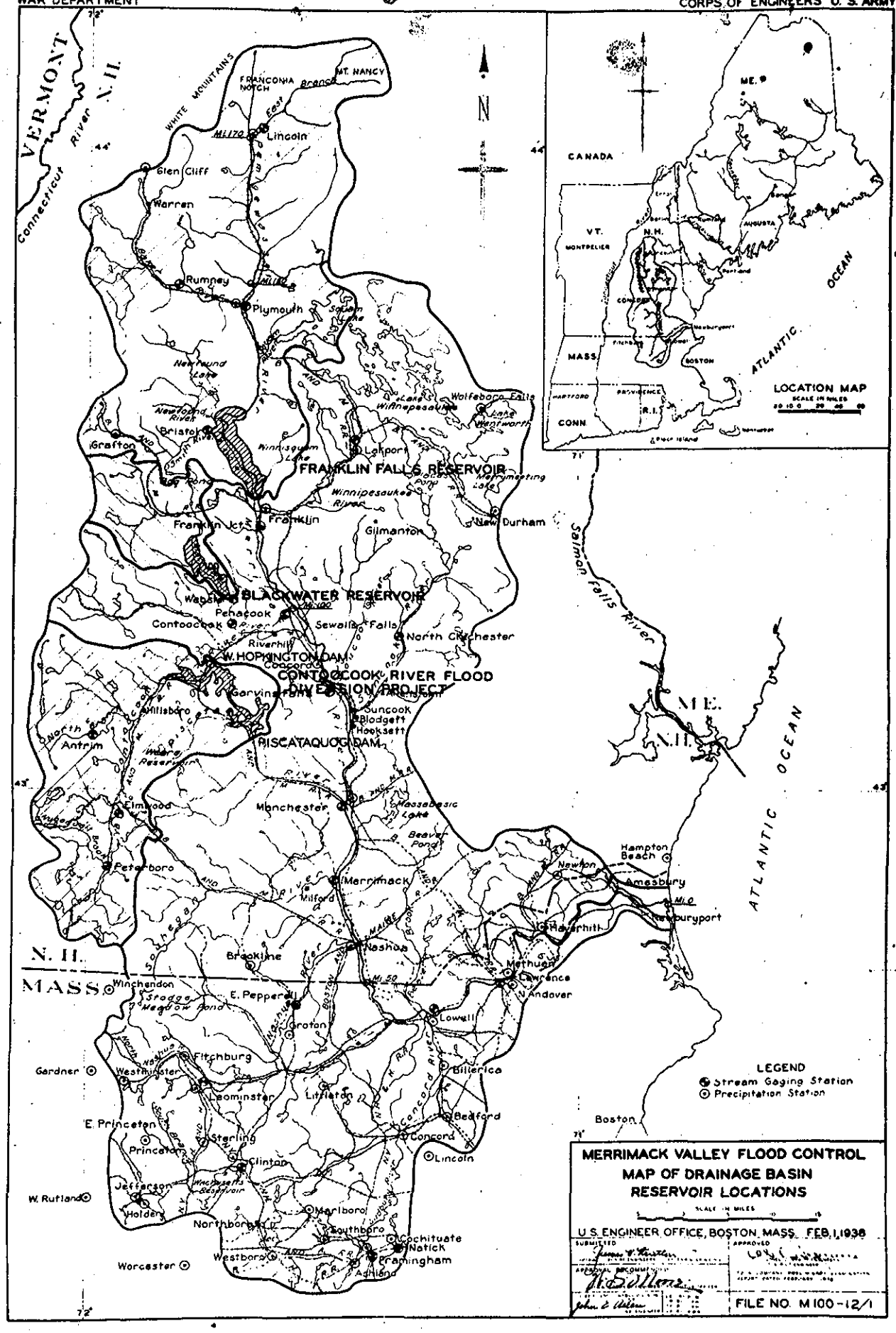
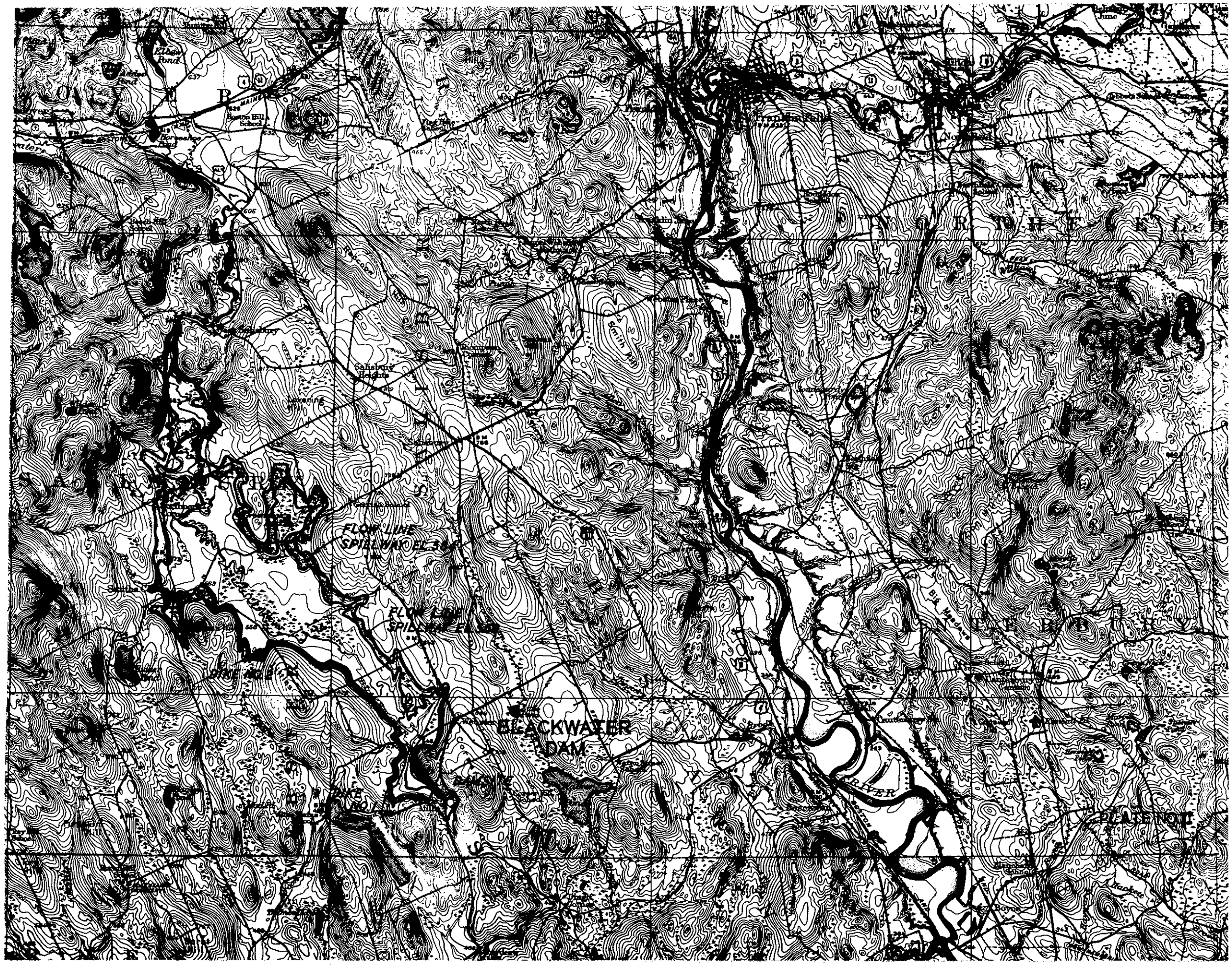
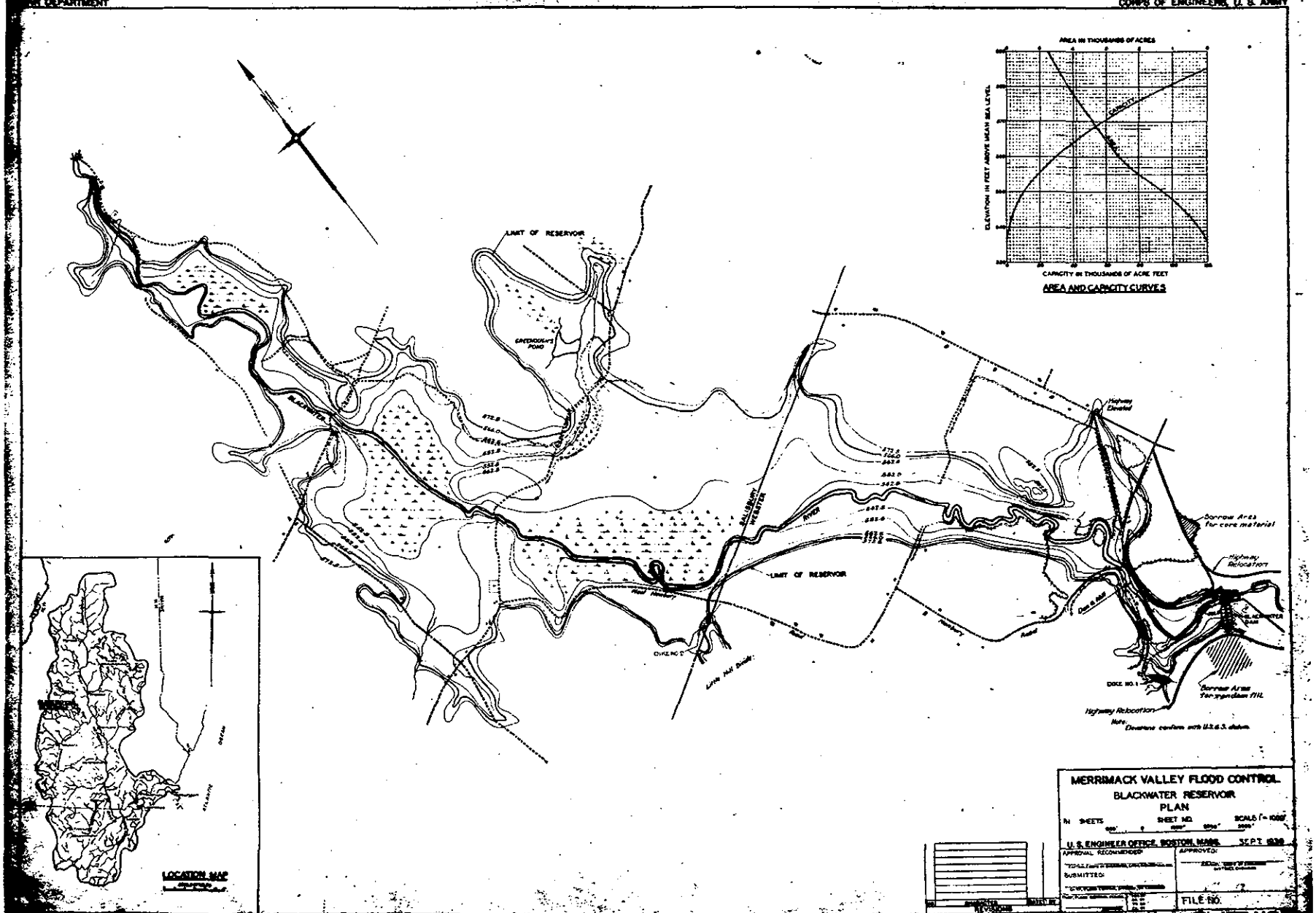


PLATE NO. I


FLOW LINE
SPILLWAY EL 584
FLOW LINE
SPILLWAY EL 584
BLACKWATER
DAM
PLATE 10E



DEPARTMENT
CORPS OF ENGINEERS, U. S. ARMY
AREA IN THOUSANDS OF ACRES
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
CAPACITY
CAPACITY IN THOUSANDS OF ACRE FEET
AREA AND CAPACITY CURVES
LIMIT OF RESERVOIR
GREENHOUGH'S POND
BLACKWATER
SALISBURY
WEBSTER
RIVER
LIMIT OF RESERVOIR
Highway Elevated
Borrow Area for core material
Highway Relocation
Borrow Area for random fill
Highway Relocation
Note: Elevations conform with U.S.G.S. datum.
LOCATION MAP
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
PLAN
IN SHEETS
SHEET NO.
SCALE 1"=1000'
U. S. ENGINEER OFFICE, BOSTON, MASS.
SEPT 1939
APPROVAL RECOMMENDED:
APPROVED:
SUBMITTED:
FILE NO.
REVISIONS

98

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

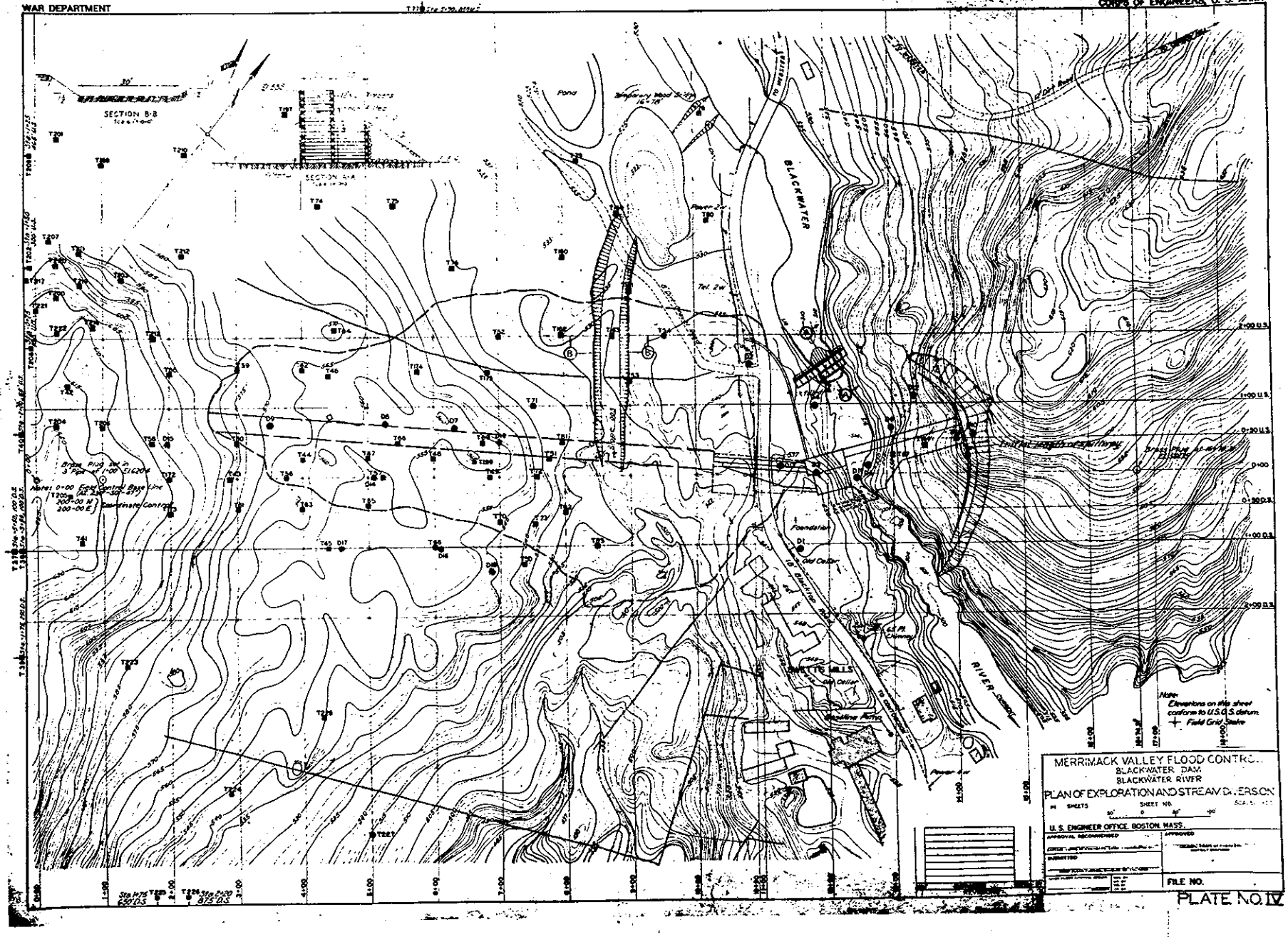
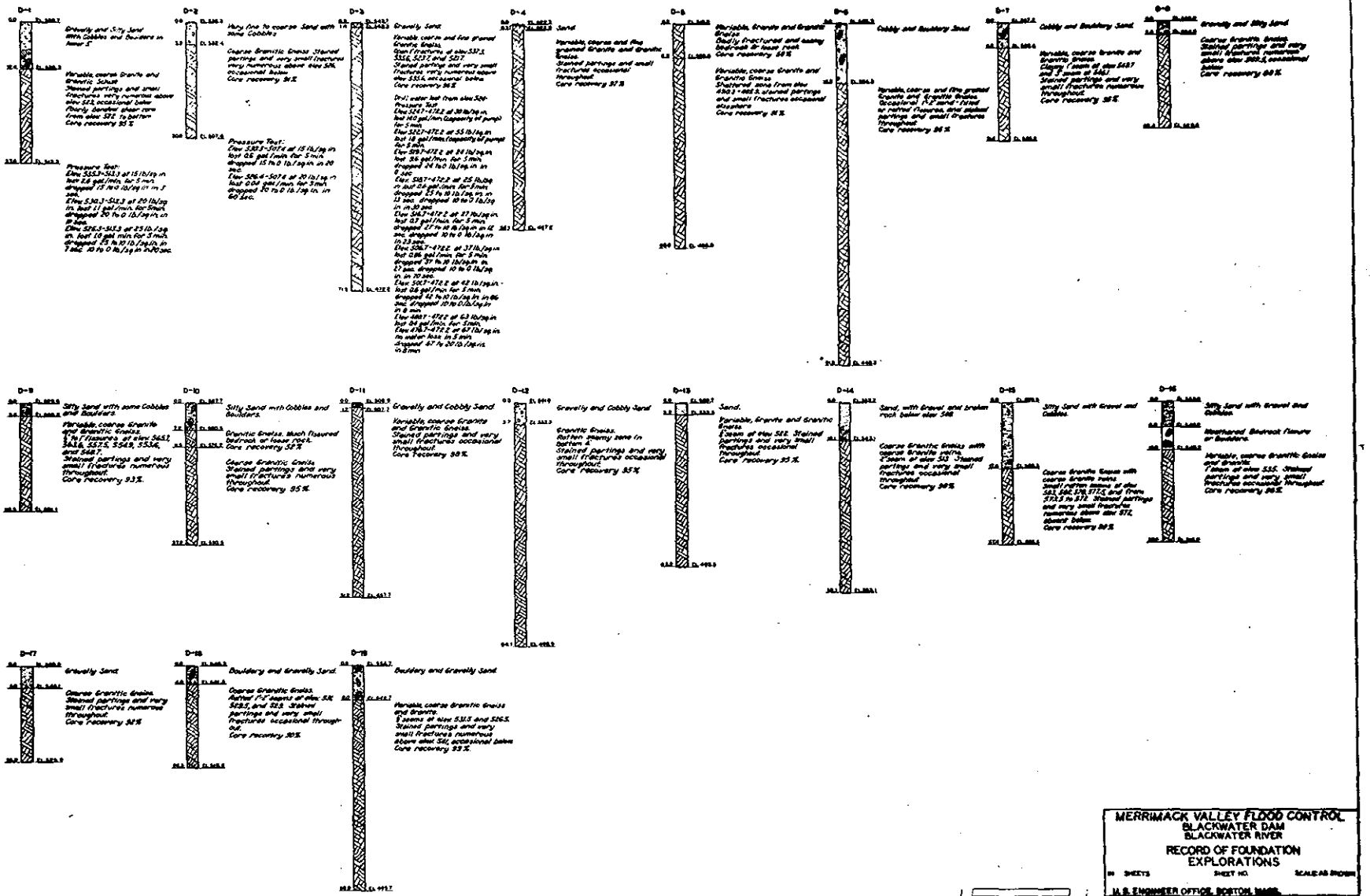


PLATE NO. IV

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER

RECORD OF FOUNDATION EXPLORATIONS

SHEETS | SHEET NO. | SCALE: AS SHOWN

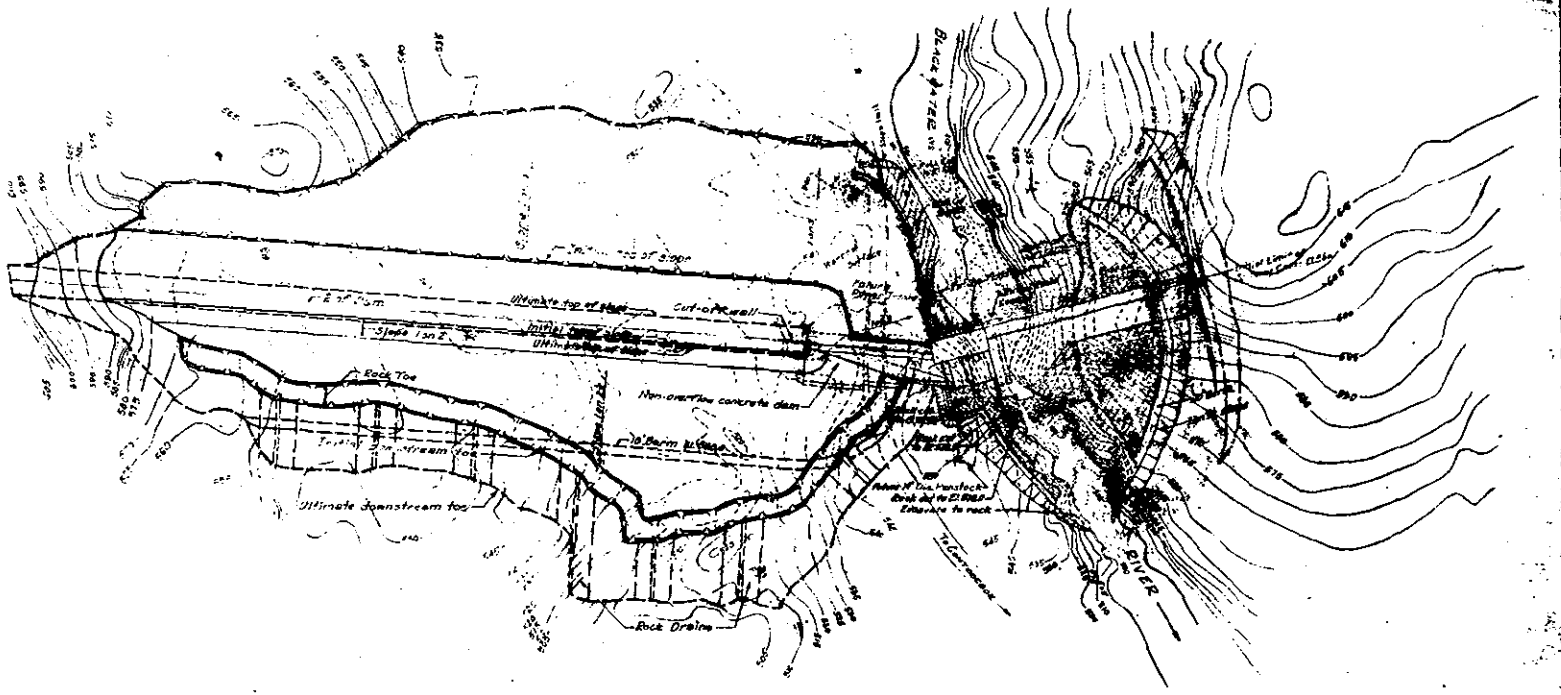
U. S. ENGINEER OFFICE, BOSTON, MASS.

FILE NO. M13 - 2/3

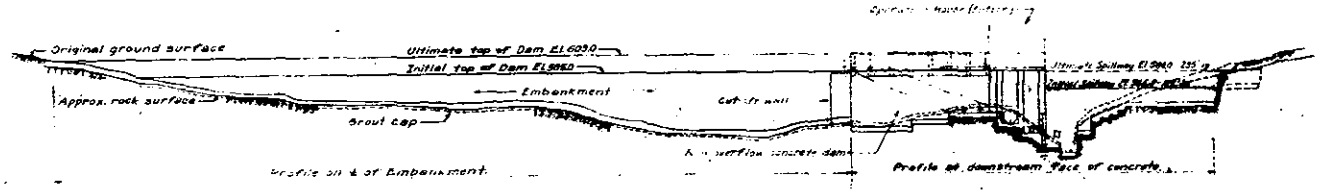
PLATE NO. 2

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



GENERAL PLAN



PROFILE

MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER

GENERAL PLAN AND PROFILE

SHEETS SHEET NO. SCALE 1" = 80 FT.

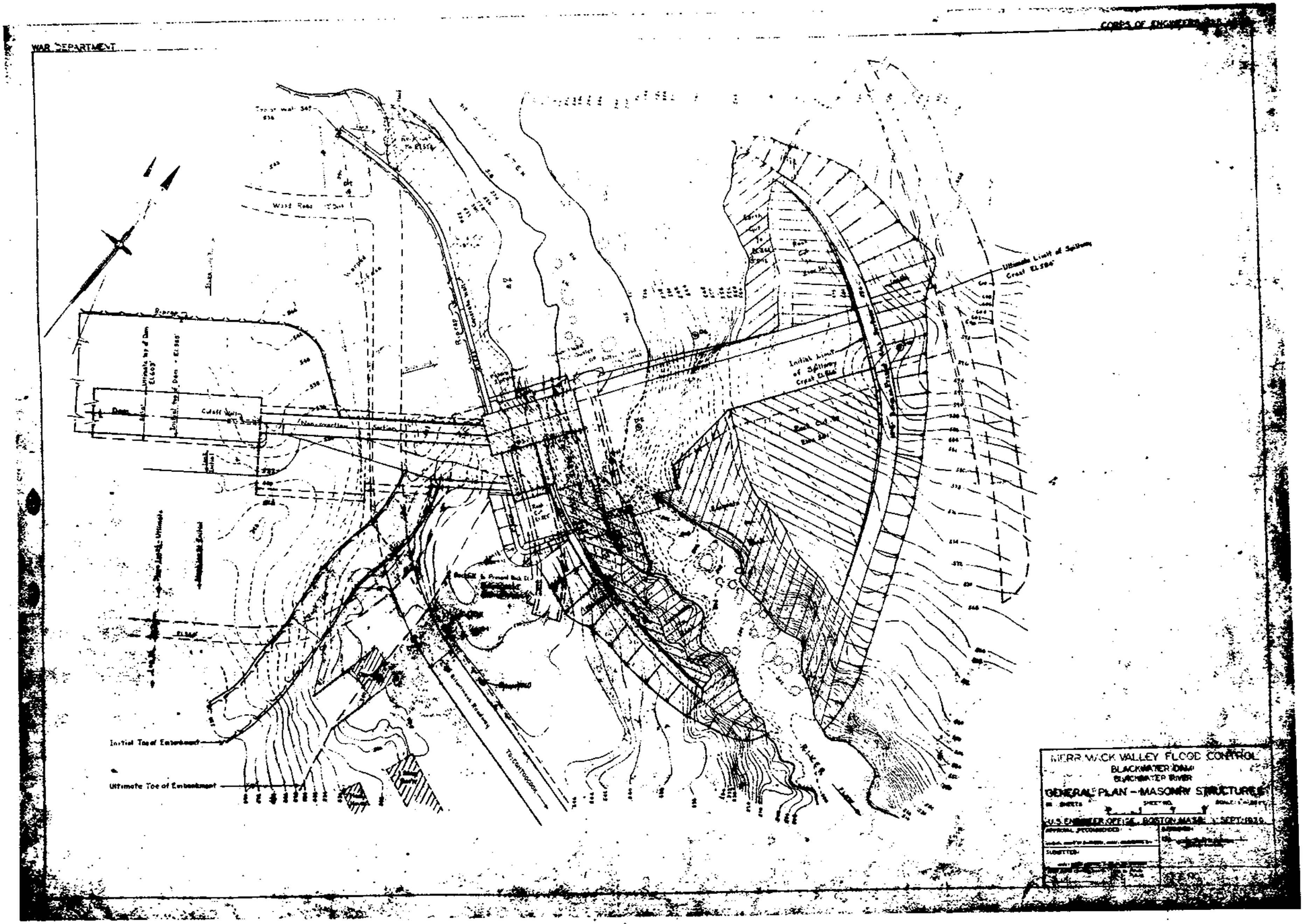
U.S. ENGINEER OFFICE, BOSTON, MASS. SEPT. 1939

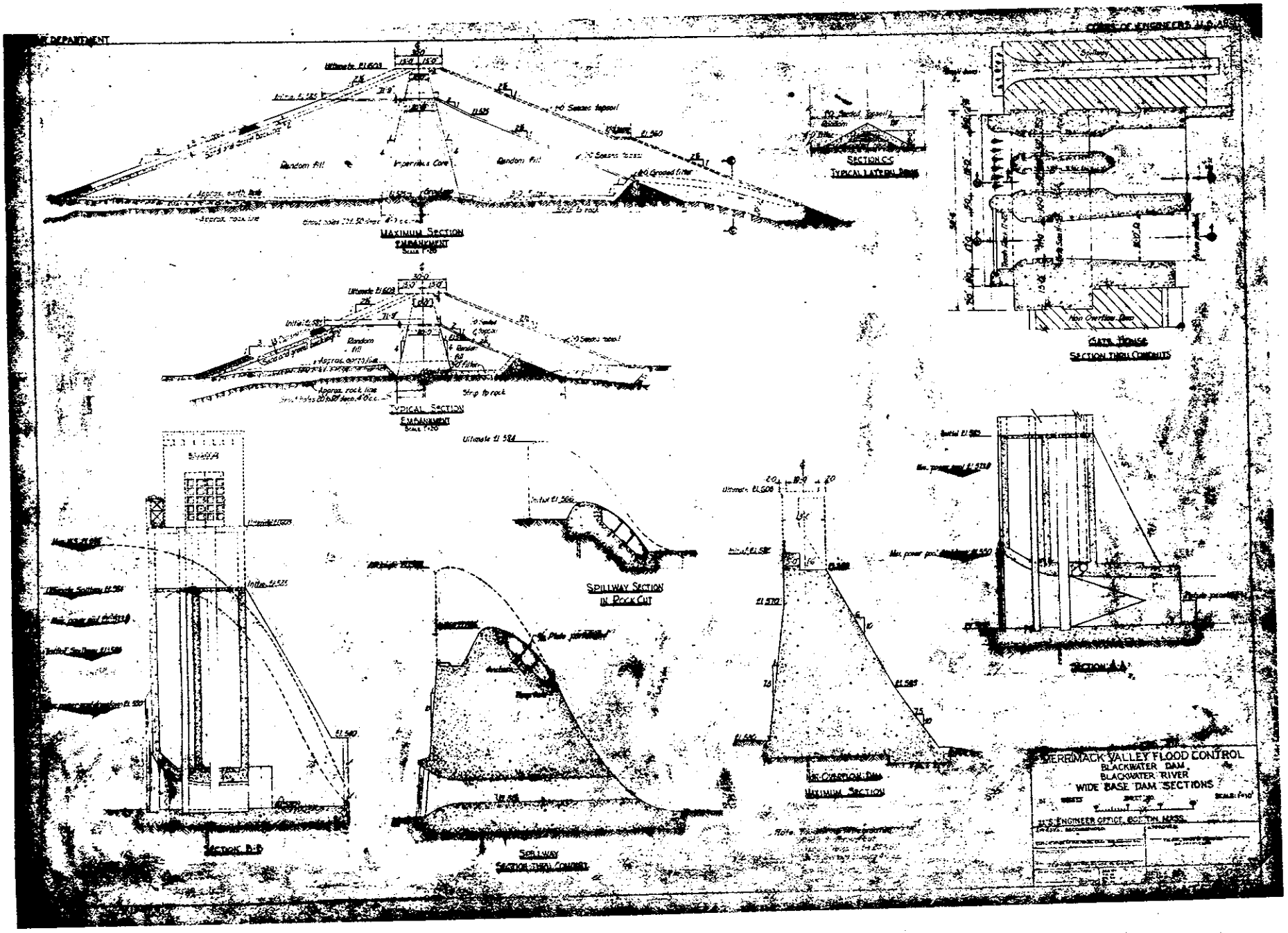
APPROVAL RECOMMENDED | APPROVED:

SUBMITTED:

FILE NO.

PLATE NO.


WAR DEPARTMENT
CORPS OF ENGINEERS
Initial Toe of Embankment
Ultimate Toe of Embankment
Cutoff Wall
Dam
Initial Limit of Spillway Crest El.586
Ultimate Limit of Spillway Crest El.586
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER
GENERAL PLAN - MASONRY STRUCTURES
U.S. ENGINEER OFFICE, BOSTON, MASS.
SUBMITTED


MAXIMUM SECTION
EMBANKMENT
TYPICAL SECTION
EMBANKMENT
SECTION C-C
TYPICAL LATERAL DRAIN
GATE HOUSE
SECTION THRU CONDUITS
SPILLWAY SECTION
IN ROCK CUT
SECTION A-A
SECTION B-B
SPILLWAY
SECTION THRU CONDUIT
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER
WIDE BASE DAM SECTIONS
U.S. ENGINEER OFFICE, BOSTON, MASS.

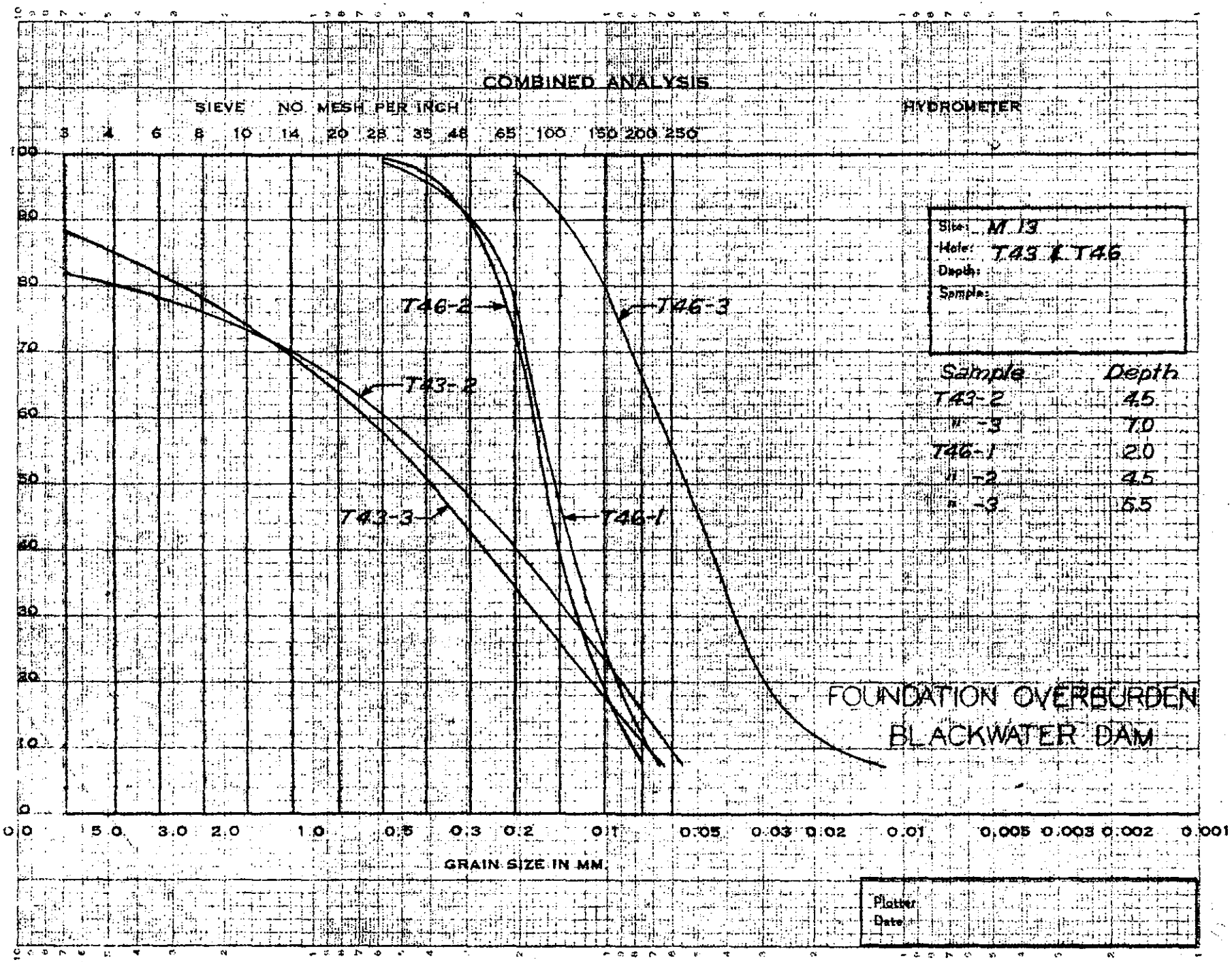

COMBINED ANALYSIS
SIEVE NO MESH PER INCH
HYDROMETER
3 4 6 8 10 14 20 28 35 48 65 100 150 200 250
% FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
10.0 5.0 3.0 2.0 1.0 0.5 0.3 0.2 0.1 0.05 0.03 0.02 0.01 0.005 0.003 0.002 0.001
GRAIN SIZE IN MM.
T46-2
T46-3
T43-2
T43-3
T46-1
Site: M 13
Hole: T43 & T46
Depth:
Sample:
Sample Depth
T43-2 4.5
" -3 7.0
T46-1 2.0
" -2 4.5
" -3 6.5
FOUNDATION OVERBURDEN
BLACKWATER DAM
Plotter
Date

PLATE NO. IX

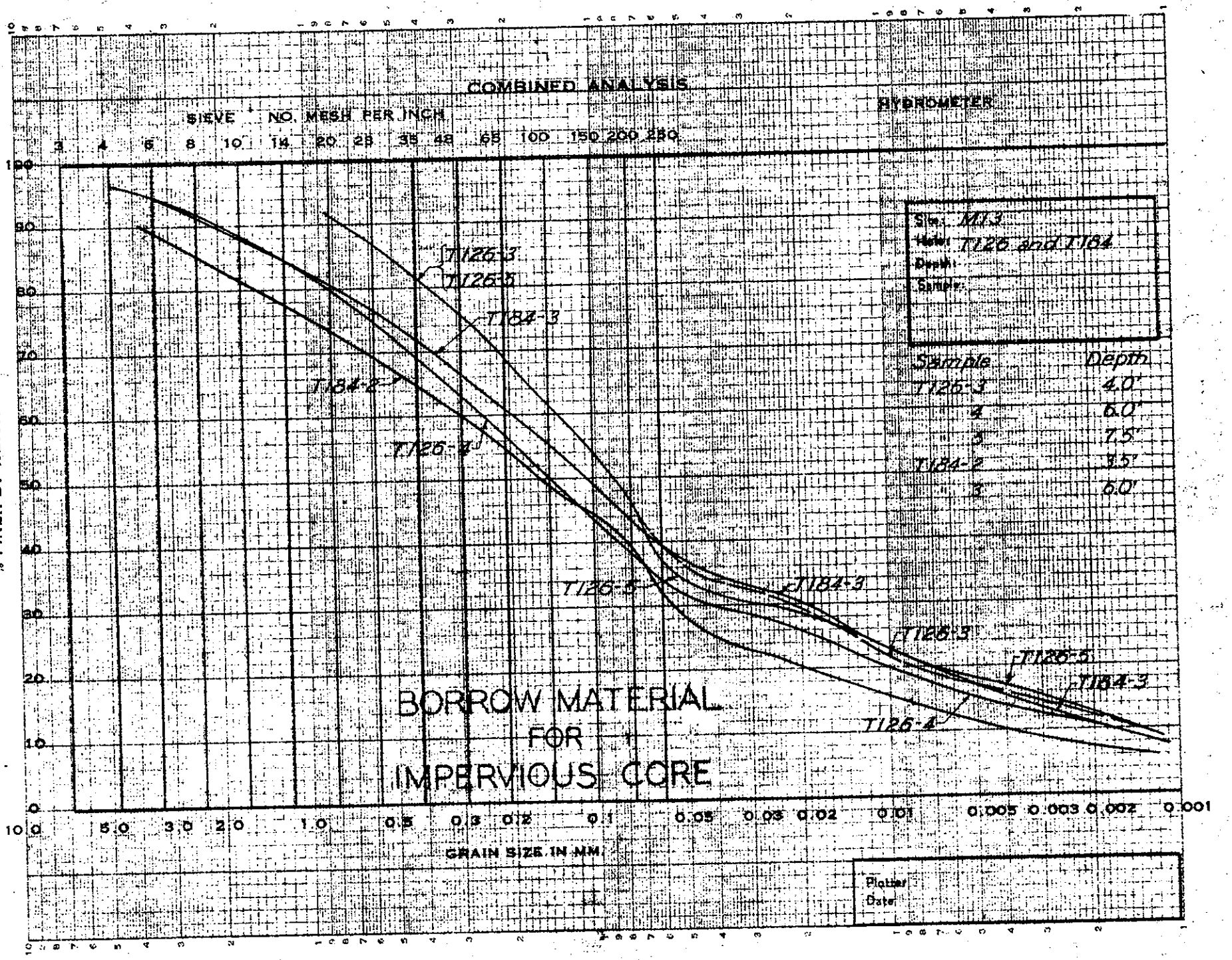

COMBINED ANALYSIS
SIEVE NO. MESH PER INCH
3 4 6 8 10 14 20 28 35 48 65 100 150 200 250
HYDROMETER
% FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
10.0 5.0 3.0 2.0 1.0 0.5 0.3 0.2 0.1 0.05 0.03 0.02 0.01 0.005 0.003 0.002 0.001
GRAIN SIZE IN MM
Site: M13
Hole: T126 and T184
Depth:
Sample:
Sample Depth
T126-3 4.0'
4 6.0'
5 7.5'
T184-2 3.5'
3 6.0'
T126-3
T126-5
T184-3
T184-2
T126-4
T126-5
T184-3
T126-3
T126-5
T184-3
T126-4
BORROW MATERIAL
FOR
IMPERVIOUS CORE
Plotter
Date

PLATE NO. X

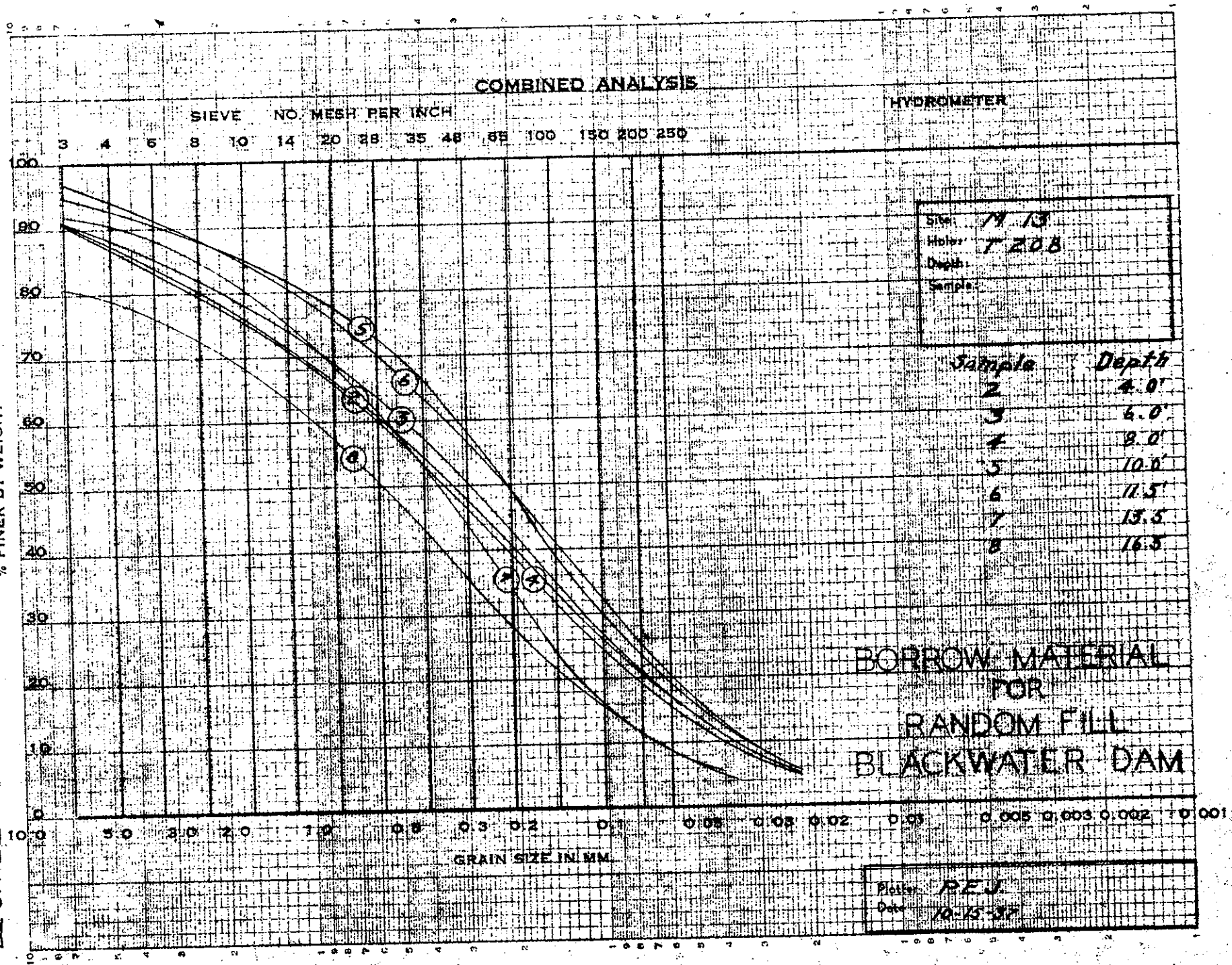

COMBINED ANALYSIS
SIEVE NO. MESH PER INCH
3 4 6 8 10 14 20 28 35 48 65 100 150 200 250
HYDROMETER
% FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
5.0 3.0 2.0 1.0 0.5 0.3 0.2 0.1 0.05 0.03 0.02 0.01 0.005 0.003 0.002 0.001
GRAIN SIZE IN MM.
Site: 14 13
Hole: T 208
Depth:
Sample:
Sample Depth
1 4.0'
2 6.0'
3 9.0'
4 10.0'
5 11.5'
6 13.5'
7 16.5'
8
BORROW MATERIAL
FOR
RANDOM FILL
BLACKWATER DAM
Plotter: RES
Date: 10-15-57

PLATE NO. XI

KEUFFEL & ESSER CO., N. Y. NO. 359-11
20 x 20 to the inch. 10th lines heavy.
MADE IN U.S.A.

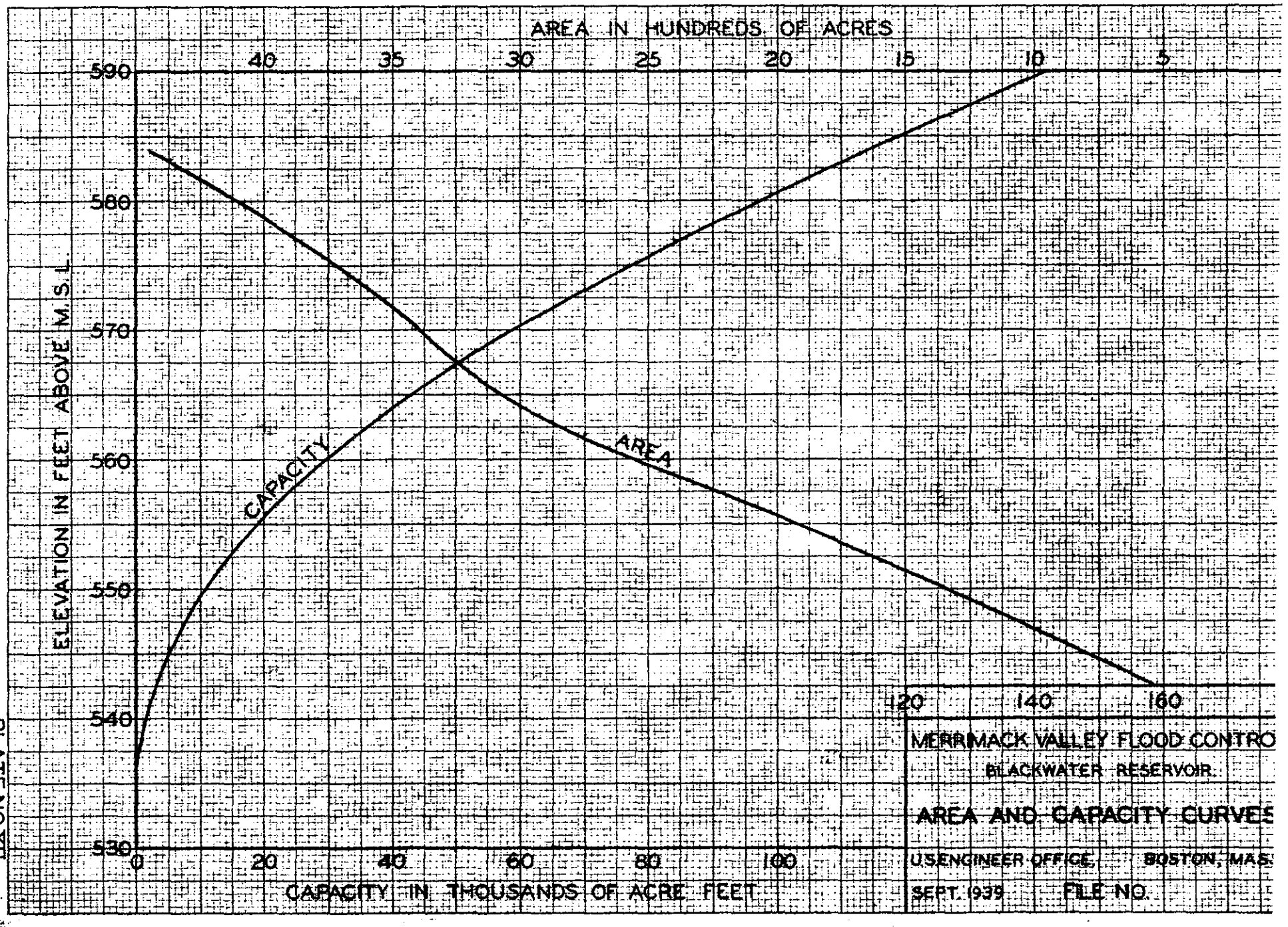
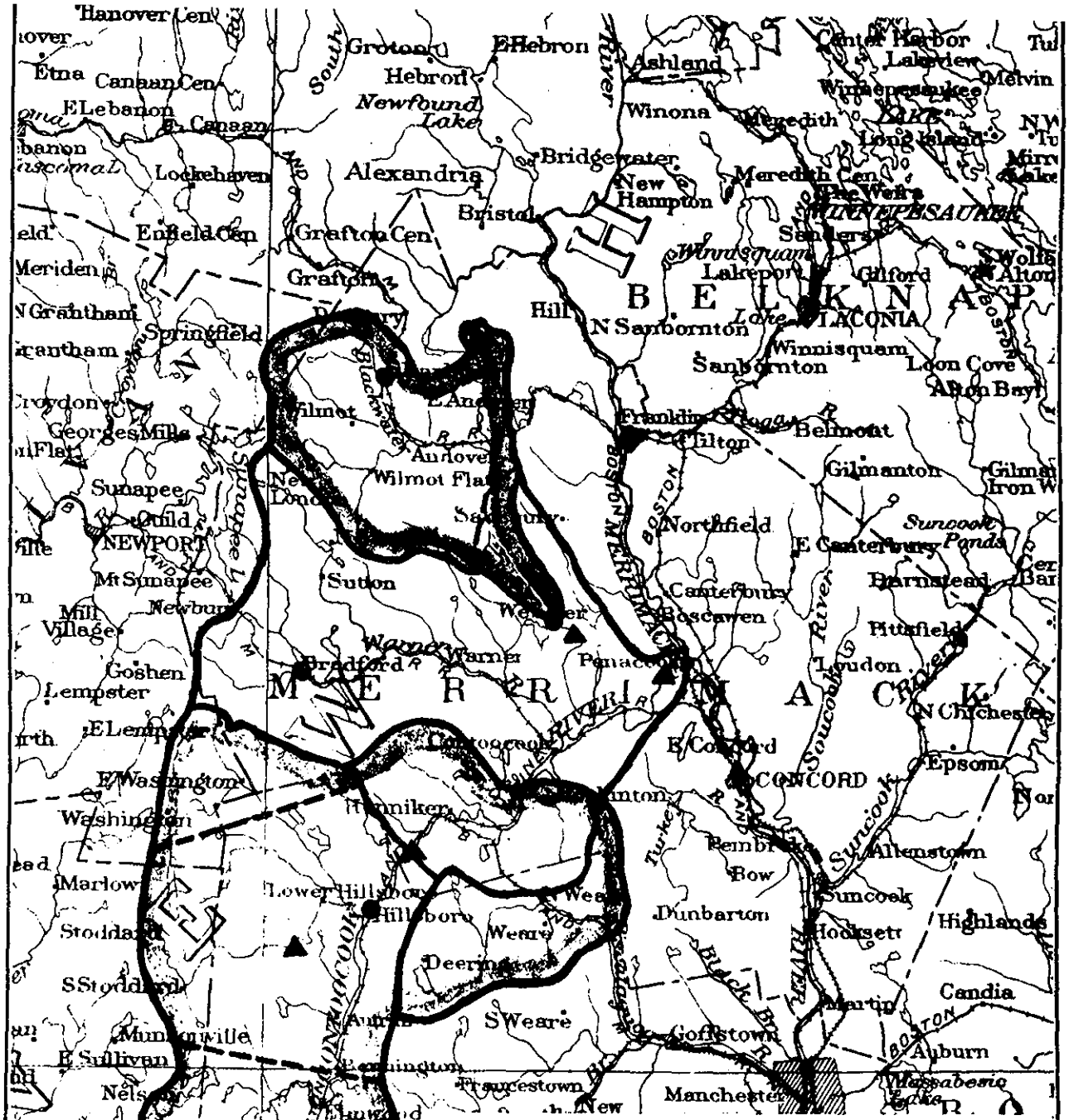


PLATE NO. XII



MERRIMACK VALLEY FLOOD CONTROL

CONTOOCOOK AND PISCATAQUOG BASINS

RAINFALL STUDIES

U.S. ENGINEER OFFICE BOSTON, MASS.

SEPT. 1939 FILE NO.

PLATE NO. XIII

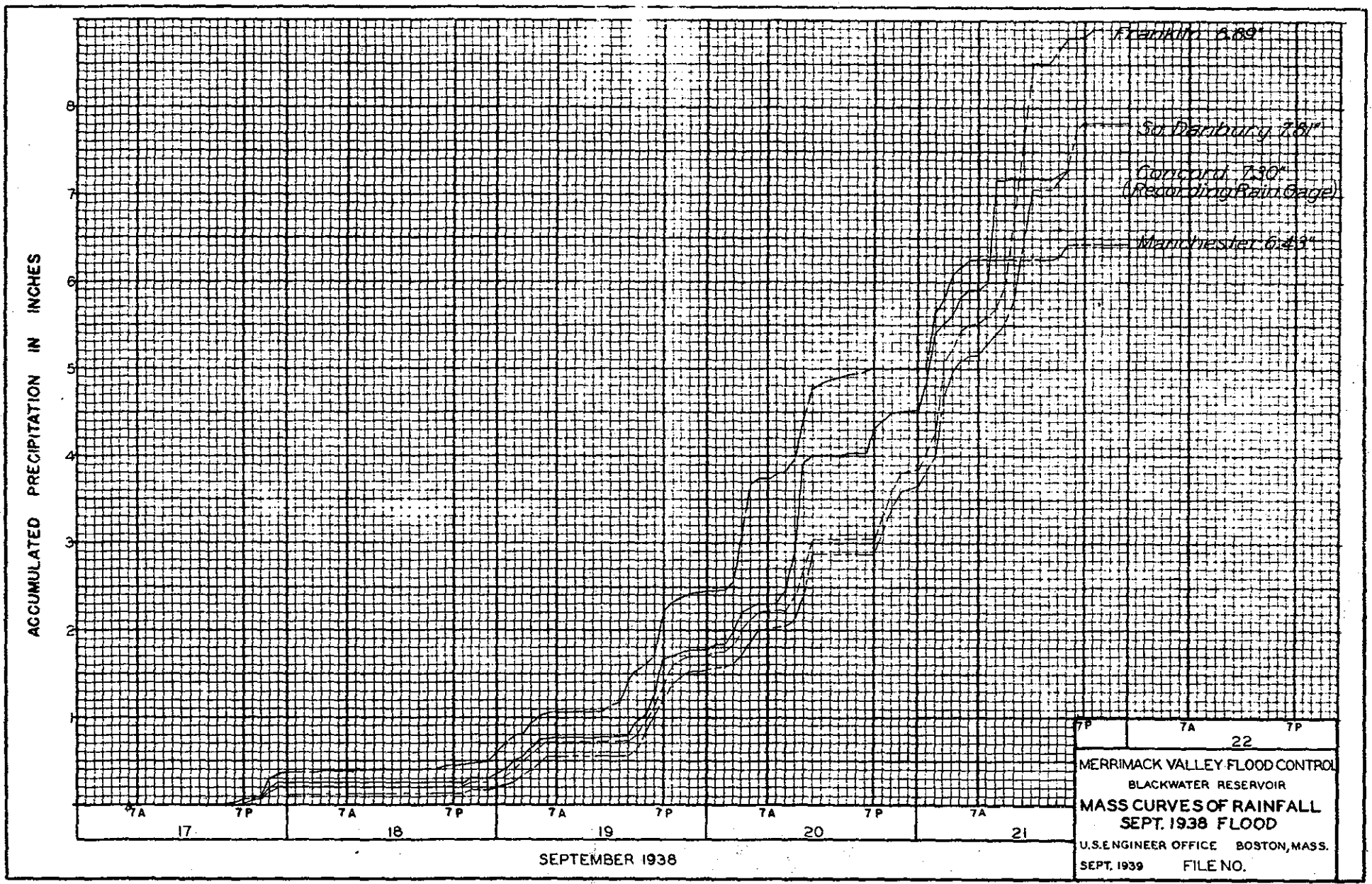
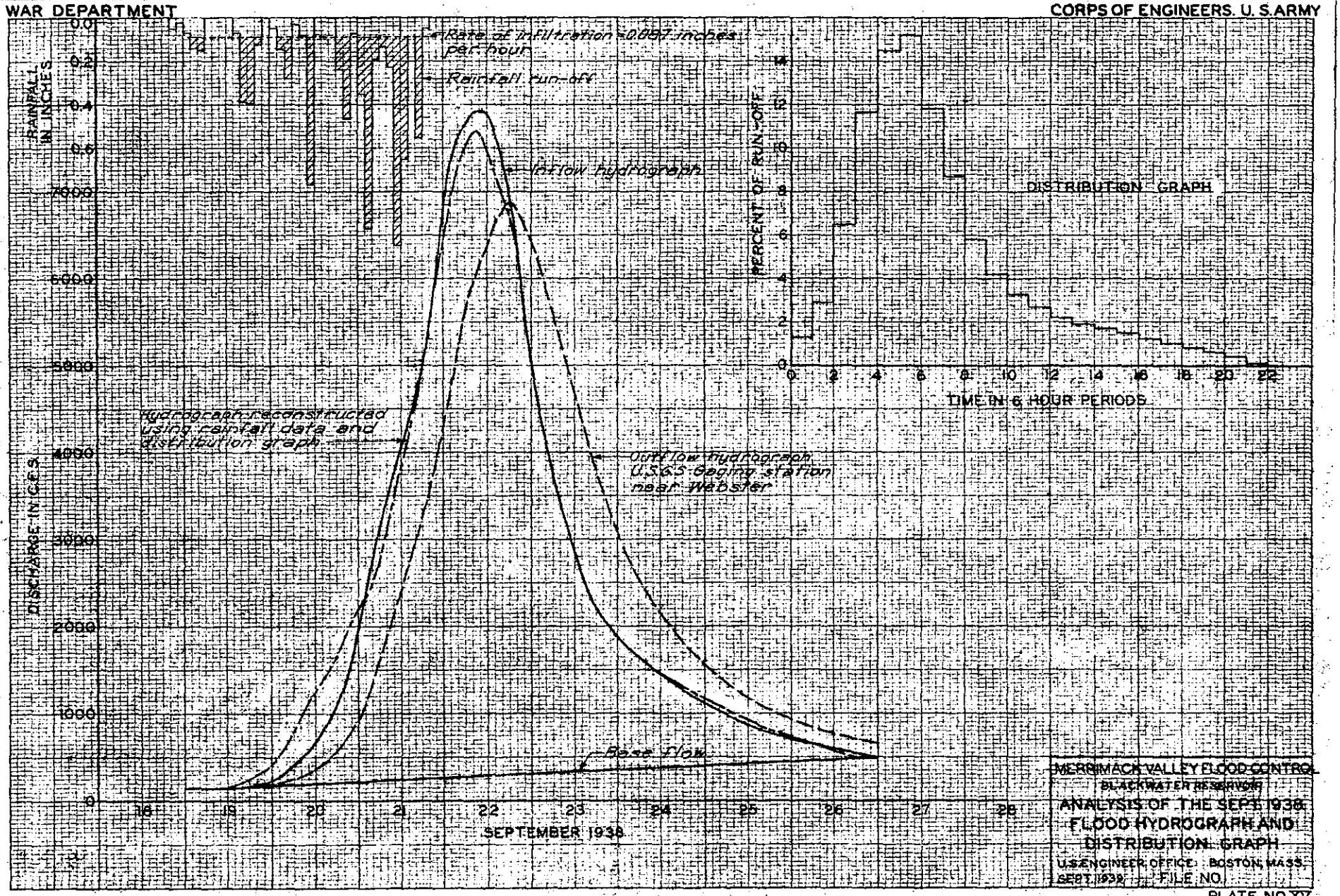

ACCUMULATED PRECIPITATION IN INCHES
1
2
3
4
5
6
7
8
7A
7P
17
18
19
20
21
22
SEPTEMBER 1938
Franklin 8.89"
So. Danbury 7.81"
Concord 7.30"
(Recording Rain Gage)
Manchester 6.49"
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
MASS CURVES OF RAINFALL
SEPT. 1938 FLOOD
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XIV

WAR DEPARTMENT

CORPS OF ENGINEERS. U. S. ARMY



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
ANALYSIS OF THE SEPT. 1938 FLOOD HYDROGRAPH AND DISTRIBUTION GRAPH
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XV

WAR DEPARTMENT
U. S. ENGINEER OFFICE, BOSTON, MASS.

Subject: Blackwater Reservoir
Computation: Derivation of Distribution Values from 1938 Flood
Computed by: E.C. Checked by: Date: 9/21/39
Page:

Sept 1938	Runoff inches	W'td Runoff dsf.	Total Inflow Hydro. dsf.	Base Flow dsf.	Net Inflow Hydro. dsf.	0.39/0.39	1.57/0.39	1.04/0.39	0.45/0.39	0.60/0.39	0.14/0.39	0.45/0.39	Distrib Values	6 Hour Periods
19 N														
6P	0.45	1537	40	37	3							21		
M	0	—	50	40	10							46		
6A	0.14	478	82	43	39						6	104		
20 N	0.60	2049	137	46	91					28	14	186		
6P	0	—	217	49	168					62	32	231		
M	0.45	1537	363	52	311				21	139	58	242		
6A	1.04	3551	650	55	595			48	46	248	72	187		
21 N	1.57	5361	888	58	830		73	107	144	308	75	138	1.3	1
6P	0.39	1332	1140	61	1079	(18) 27	167	240	186	323	58	84	2.9	2
M			1460	64	1396	(40) 13	362	430	231	250	43	67	6.5	3
6A			1875	67	1808	(90) 116	650	534	242	185	29	52	11.7	4
22 N			1970	70	1900	161	805	560	187	123	21	43	14.5	5
6P			1875	73	1802	(200) 247	845	432	138	89	16	35	15.2	6
M			1500	76	1424	(210) 248	652	320	92	69	13	30	11.8	7
6A			1090	79	1019	162	482	214	67	57	11	26	8.7	8
23 N			825	82	743	(120) 136	322	155	52	46	9	23	5.8	9
6P			625	85	540	(80) 75	234	120	43	40	8	20	4.2	10
M			510	88	422	(58) 49	181	99	35	35	7	16	3.3	11
6A			438	91	347	(45) 38	149	80	30	31	6	13	2.7	12
24 N			388	94	294	37	121	70	26	26	5	9	2.2	13
6P			338	97	241	(30) 20	105	61	23	22	4	6	1.9	14
M			300	100	200	(26) 11	93	53	20	17	3	3	1.7	15
6A			262	103	159	(23) 3	81	45	16	12	2		1.5	16
25 N			230	106	124	(20) -3	68	37	13	8	1		1.2	17
6P			207	109	98	(17) -1	56	29	9	5			1.0	18
M			188	112	76	(14) 5	44	21	6				0.8	19
6A			175	115	60	(11) 12	32	13	3				0.6	20
N			155	118	37	(8) 9	20	8					0.4	21
6P			142	121	21	(5) 9	12						0.1	22
M			130	124	6	(3) 6								
	4.64	15845			15845		5548						100.0	

PLATE NO. XVI

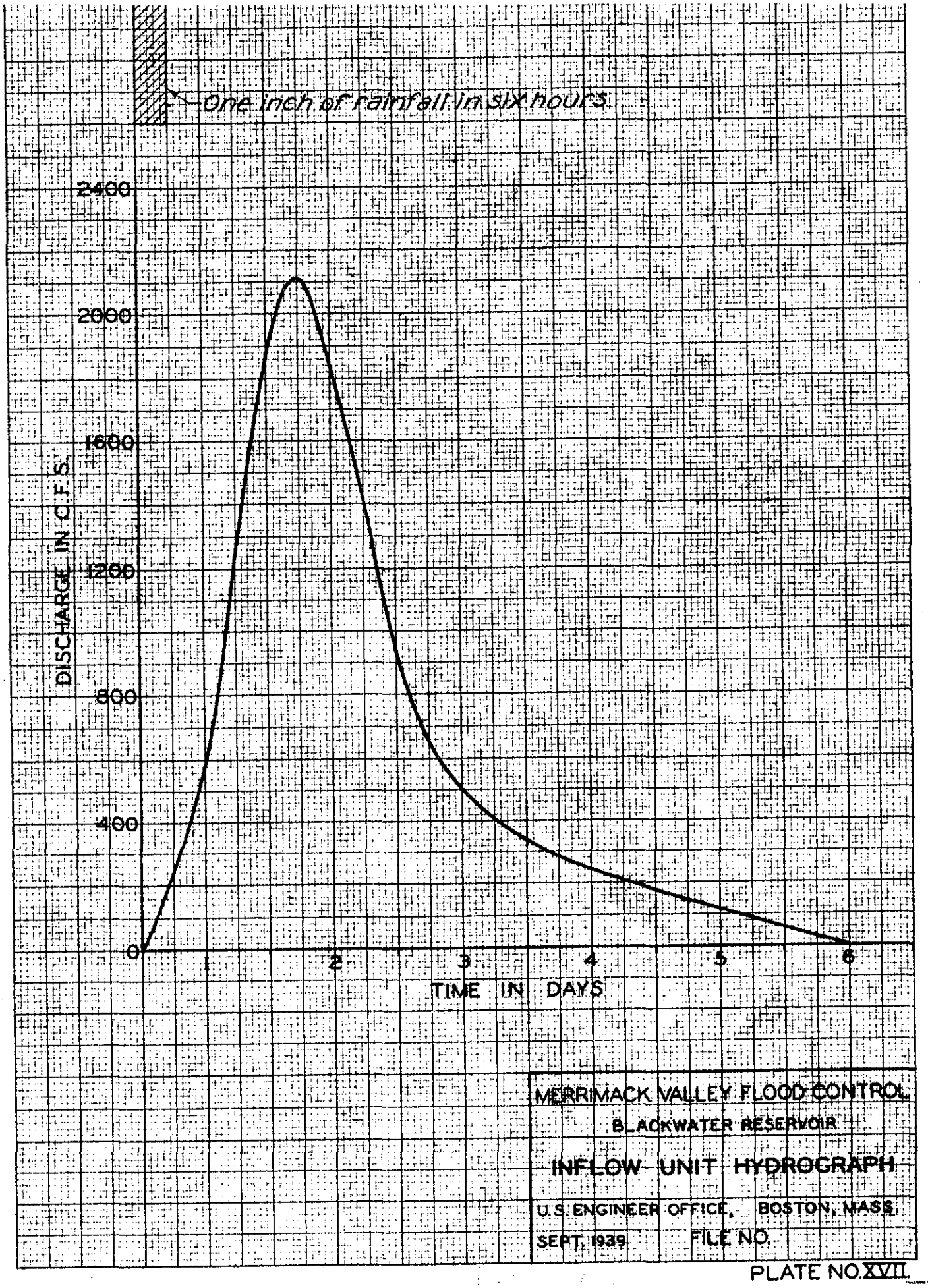
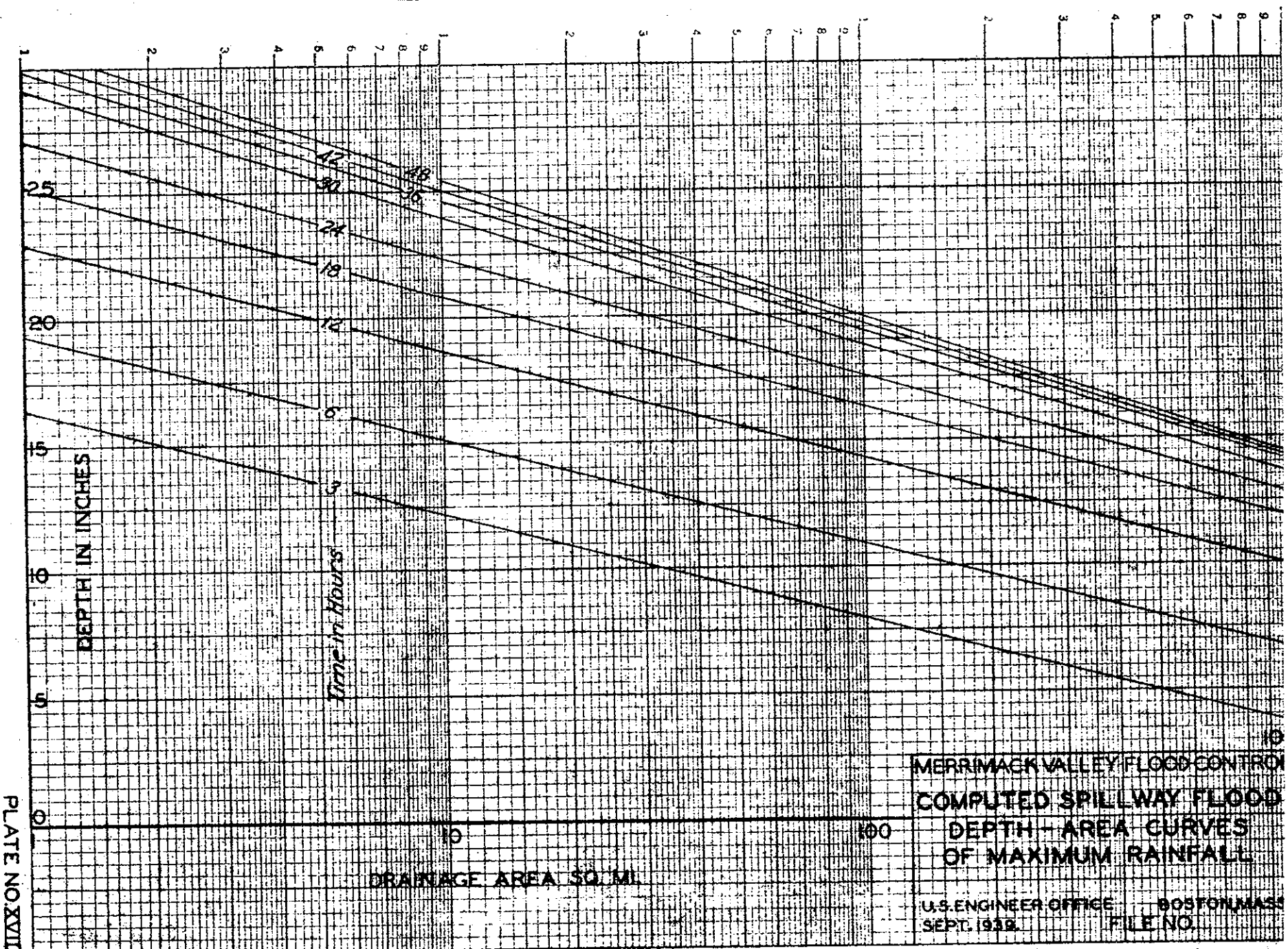


PLATE NO. XVII

KEUFFEL & ESSER CO., N. Y. NO. 359-11
20 X 20 to the inch, 10th lines heavy.
MADE IN U.S.A.

KEUFFEL & ESSER CO., N. Y. NO. 359-71
Semi-Logarithmic, 3 Cycles × 70 to the inch.
MADE IN U. S. A.



MERRIMACK VALLEY FLOOD CONTROL
COMPUTED SPILLWAY FLOOD
DEPTH – AREA CURVES
OF MAXIMUM RAINFALL

U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939. FILE NO.

PLATE NO. XVIII

WAR DEPARTMENT
U. S. ENGINEER OFFICE, BOSTON, MASS.

Subject: Blackwater Reservoir
Computation: Computed Spillway Flood
Computed by: F.M.S. Checked by: Date: 9/8/39
Page

Period	Rainfall inches	Runoff (Infilt. rate 0.083"/hr) inches	Runoff d.s.f.	Distrib. values	Distributed Runoff - d.s.f. 1.	2.	3.	4.	5.	6.	Total Runoff d.s.f.	Total Runoff d.s.f. 1/4 day	Total Runoff plus 2 cfs/mi base flow added d.s.f. 1/4 day
M	0.4												
6A	1.1	0.6	2057	1.3	27						27	108	358
1-N	2.0	1.5	5143	2.9	60	67					127	508	758
6P	10.5	10.0	34283	6.5	134	149	446				729	2916	3166
M	3.4	2.9	9942	11.7	240	334	995	129			1698	6792	7042
6A	1.2	0.7	2400	14.5	298	601	2230	288	31		3448	13792	14042
2-N	0.6	0.1	343	15.2	312	745	4010	646	70	4	5787	23148	23398
6P	0.2			11.8	242	781	4970	1160	156	10	7319	29276	29526
M				8.7	179	606	5210	1440	281	22	7738	30952	31202
6A				5.8	119	447	4050	1510	348	40	6514	26056	26306
3-N				4.2	86	298	2980	1170	365	50	4949	19796	20046
6P				3.3	68	216	1990	865	283	52	3474	13896	14146
M				2.7	56	169	1440	576	209	40	2490	9960	10210
6A				2.2	45	139	1130	417	139	30	1900	7600	7850
4-N				1.9	39	113	925	328	101	20	1526	6104	6354
6P				1.7	35	98	754	268	79	14	1248	4992	5242
M				1.5	31	87	652	218	65	11	1064	4256	4506
6A				1.2	25	77	583	189	53	9	936	3744	3994
5-N				1.0	21	62	514	169	46	8	840	3360	3610
6P				0.8	16	51	411	149	41	7	675	2700	2950
M				0.6	12	41	343	119	36	6	557	2228	2478
6A				0.4	8	31	274	99	29	5	446	1784	2034
6-N				0.1	2	21	206	80	24	4	337	1348	1598
6P						5	137	60	19	3	224	896	1146
M							34	40	14	3	91	364	614
6A								10	10	2	22	88	338
7-N									2	1	3	12	262
	19.4	15.8	54168	100.0							54169	216676	223176

PLATE NO. XIX

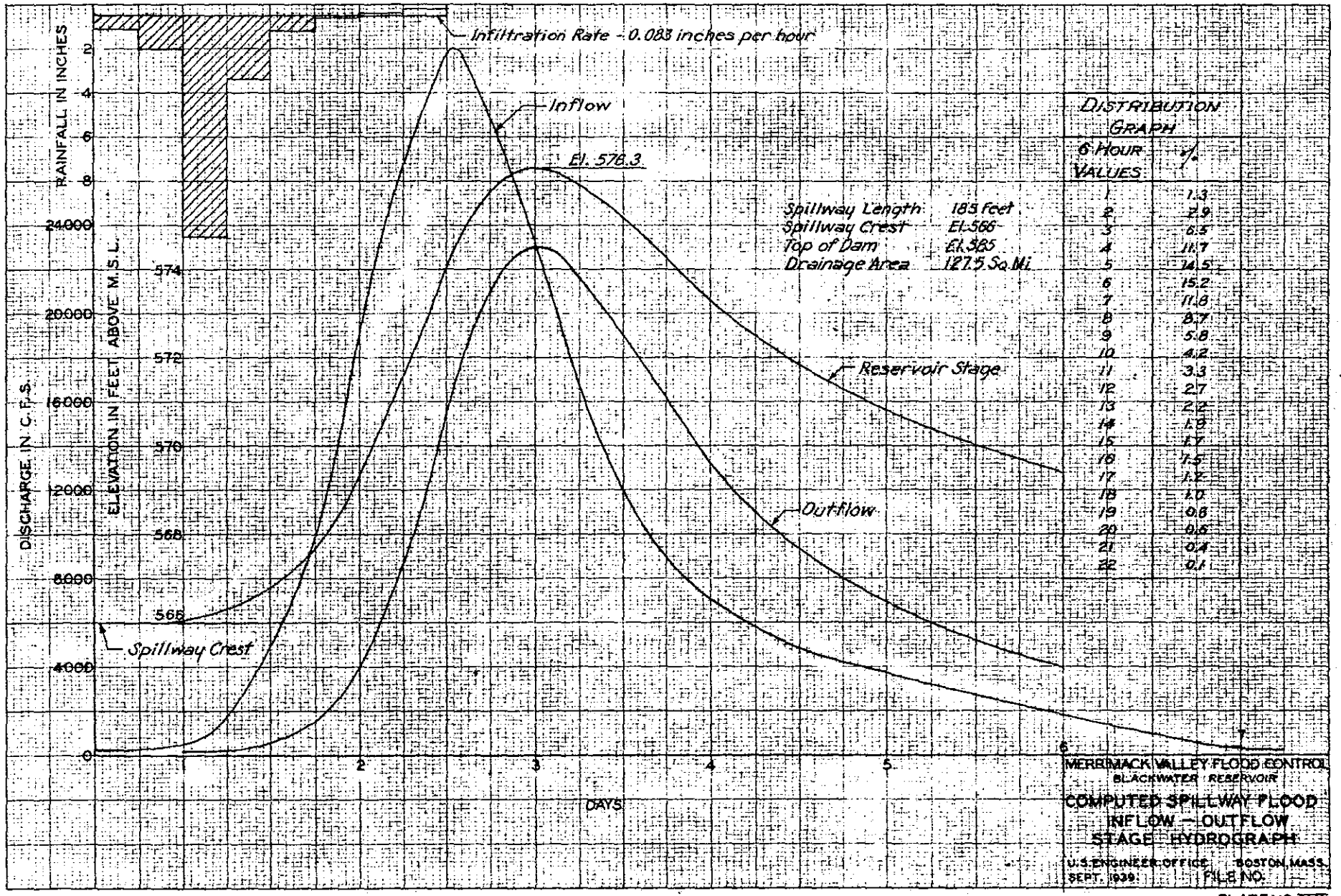
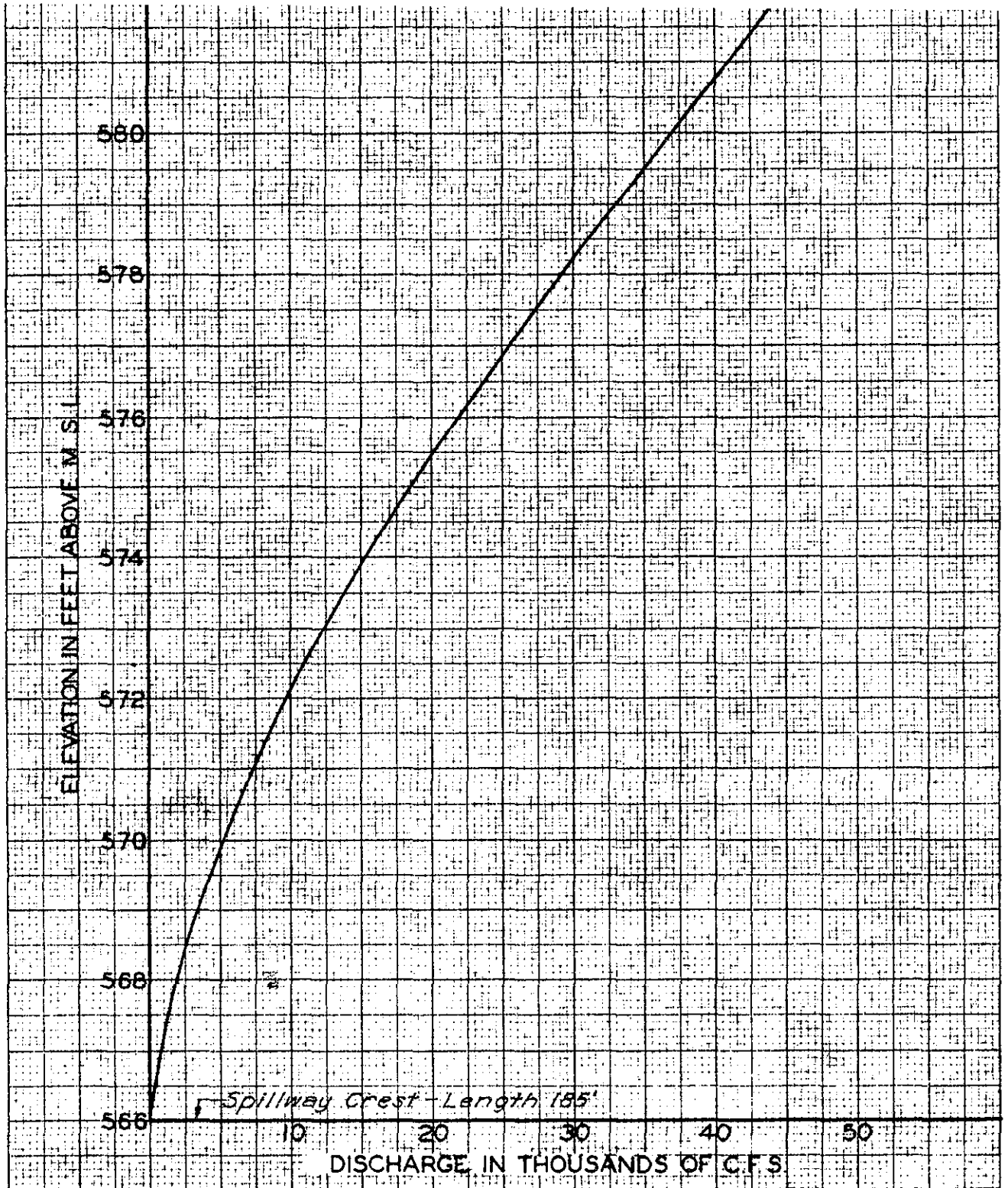

RAINFALL IN INCHES
2
4
6
8
Infiltration Rate - 0.083 inches per hour
Inflow
El. 576.3
Reservoir Stage
Outflow
Spillway Crest
DISCHARGE IN C.F.S.
24000
20000
16000
12000
8000
4000
0
ELEVATION IN FEET ABOVE M.S.L.
574
572
570
568
566
1
2
3
4
5
6
7
DAYS
Spillway Length 185 Feet
Spillway Crest El. 566
Top of Dam El. 585
Drainage Area 127.5 Sq. Mi.
DISTRIBUTION GRAPH
6 HOUR VALUES
% 1 1.3 2 7.9 3 6.5 4 11.7 5 14.5 6 15.2 7 11.8 8 8.7 9 5.8 10 4.2 11 3.3 12 2.7 13 2.2 14 1.9 15 1.7 16 1.5 17 1.2 18 1.0 19 0.8 20 0.6 21 0.4 22 0.1
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
COMPUTED SPILLWAY FLOOD
INFLOW — OUTFLOW
STAGE HYDROGRAPH
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XX

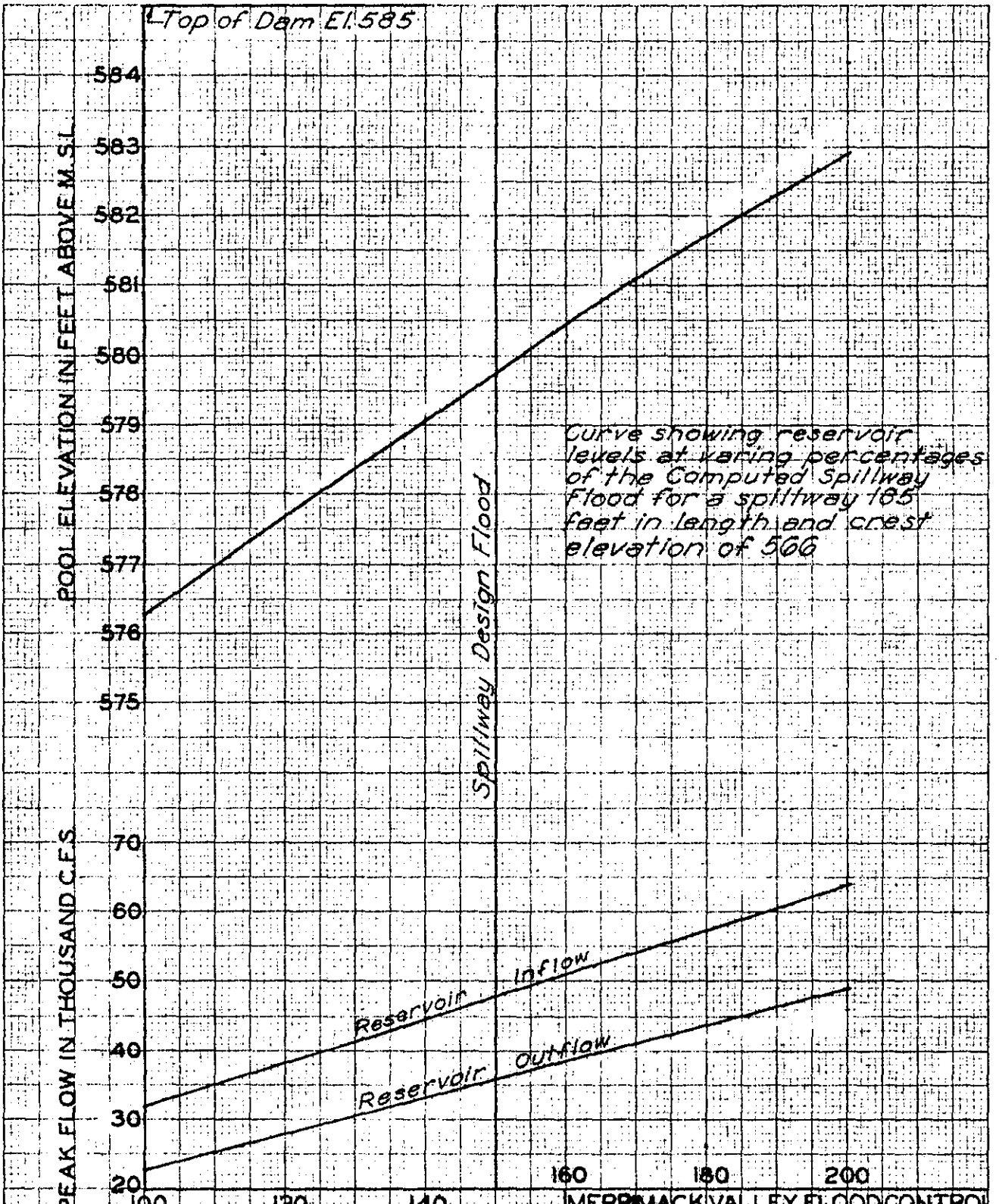


MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR

SPILLWAY RATING CURVE

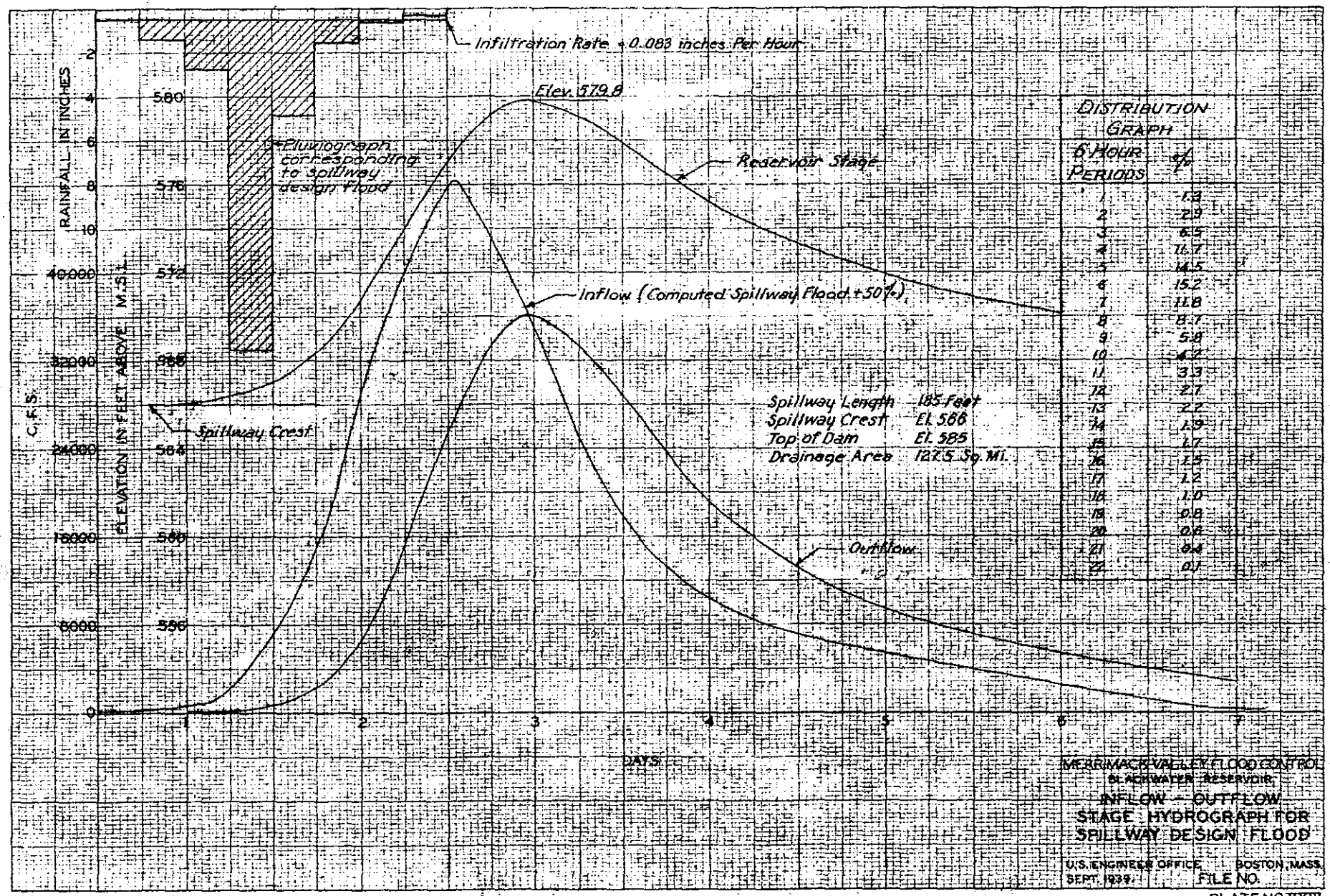
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XXI



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
PER CENT OF COMPUTED SPILLWAY FLOOD VS. PEAK FLOW AND POOL ELEVATION
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

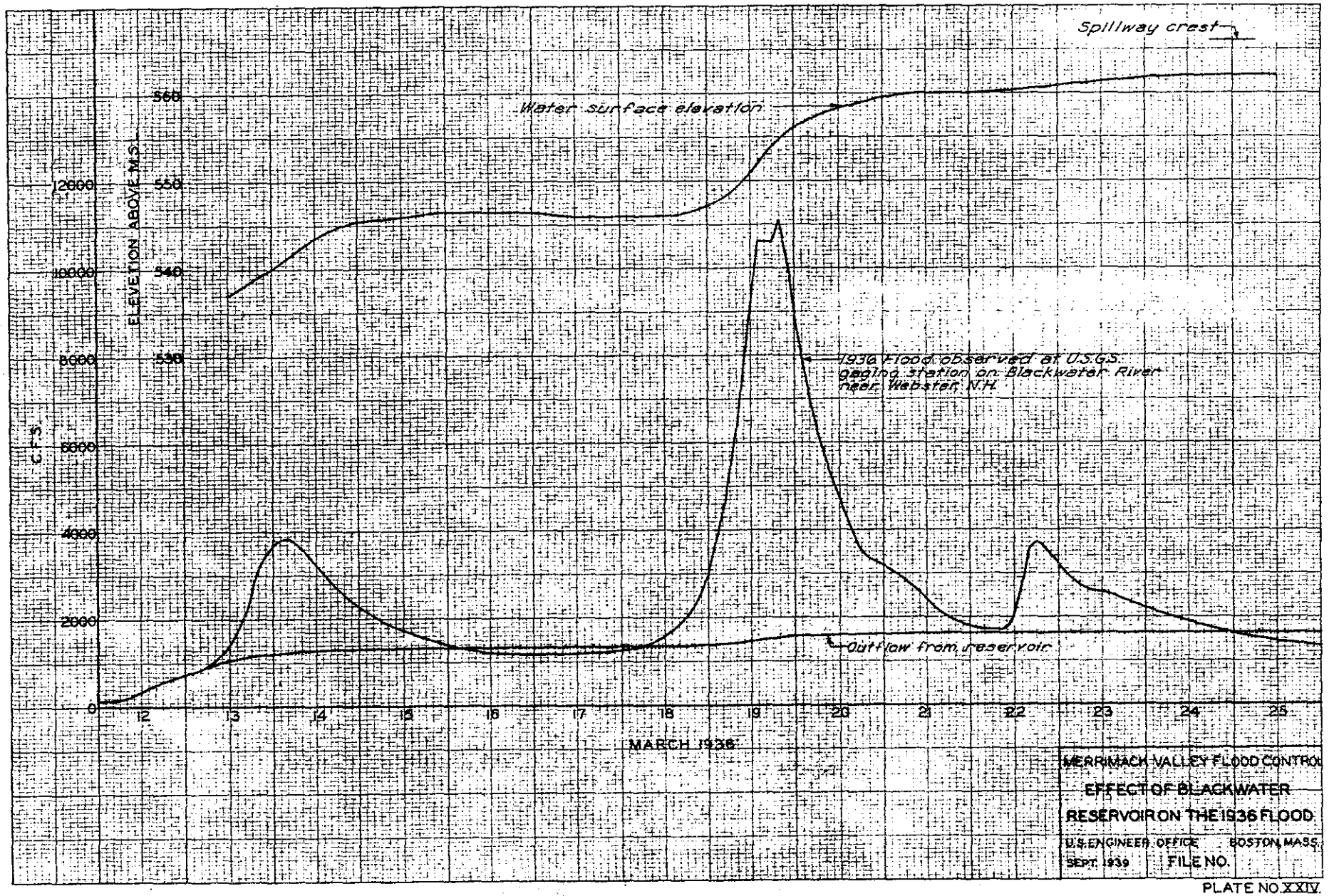
PLATE NO. XXII.



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
INFLOW - OUTFLOW
STAGE HYDROGRAPH FOR
SPILLWAY DESIGN FLOOD

U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XXIII



MERRIMACK VALLEY FLOOD CONTROL

EFFECT OF BLACKWATER RESERVOIR ON THE 1936 FLOOD.

U.S. ENGINEER OFFICE BOSTON, MASS.

SEPT. 1939 FILE NO.

PLATE NO. XXIV.

Fig 2

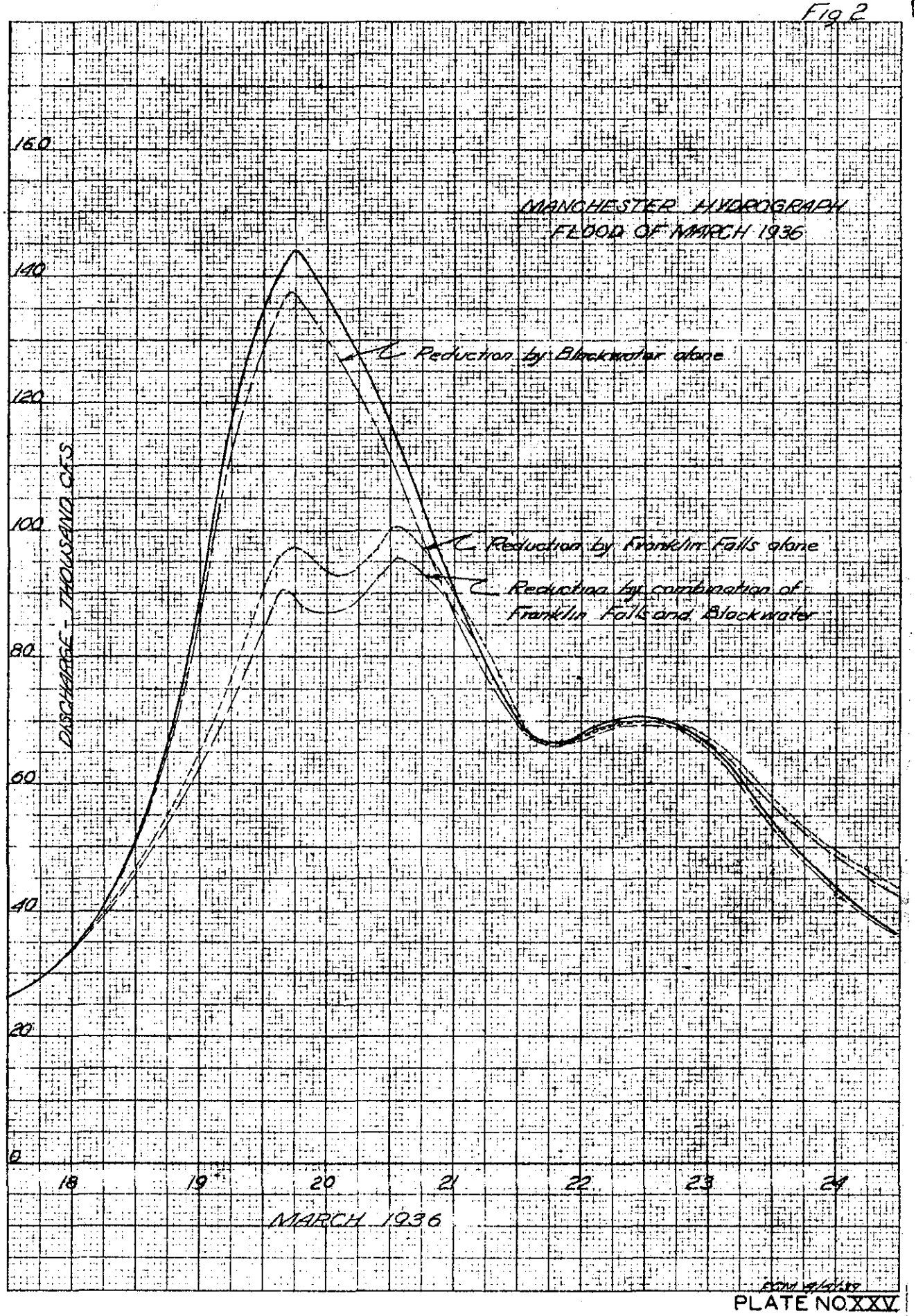


PLATE NO. XXV

KEUFFEL & ESSER CO., N. Y. NO. 359-11
20 X 20 to the inch, 19th lines heavy.
MADE IN U.S.A.

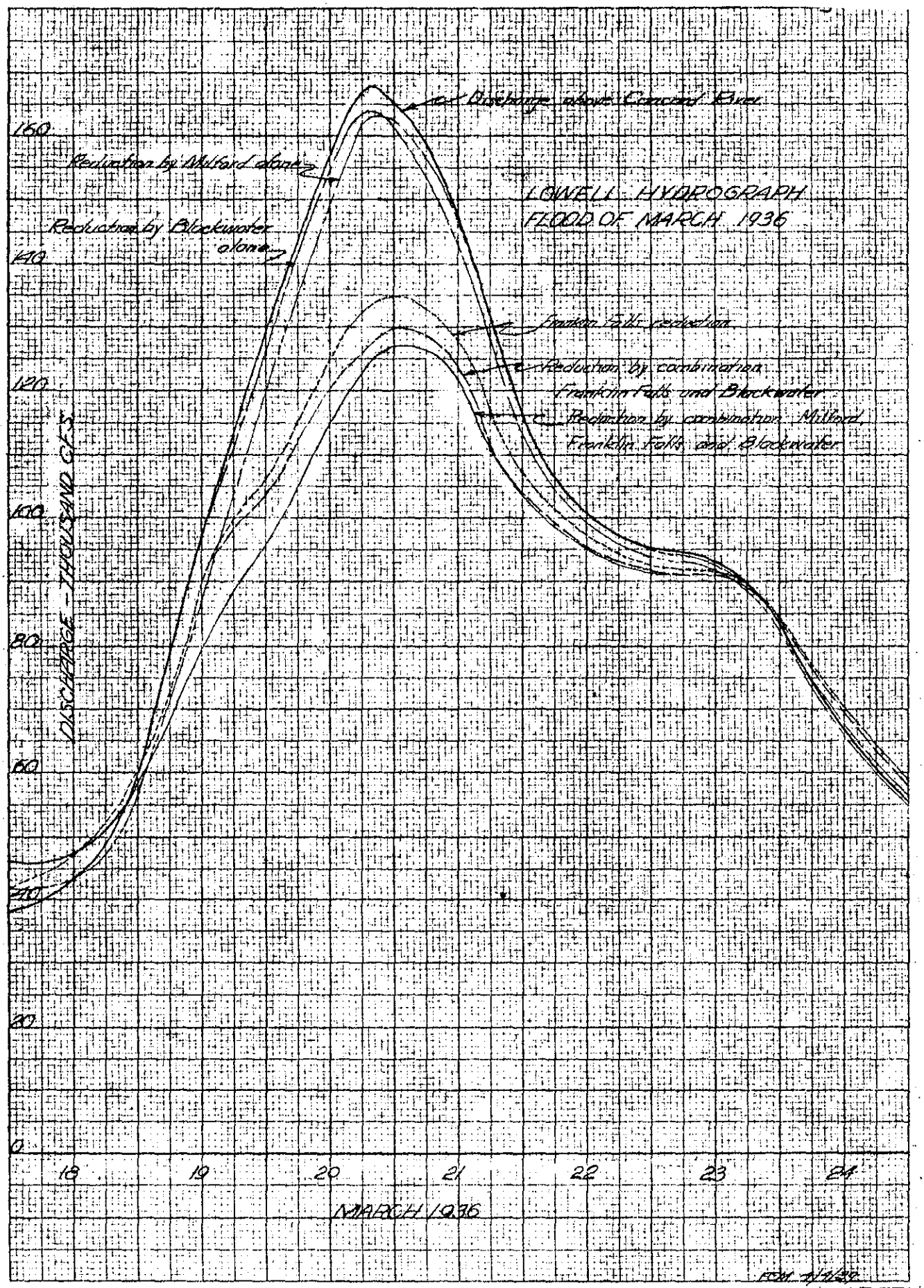


PLATE NO XXVI

KEUFFEL & ESSER CO., N. Y. NO. 359-11
20 X 20 to the inch. 10th lines heavy.
MADE IN U. S. A.

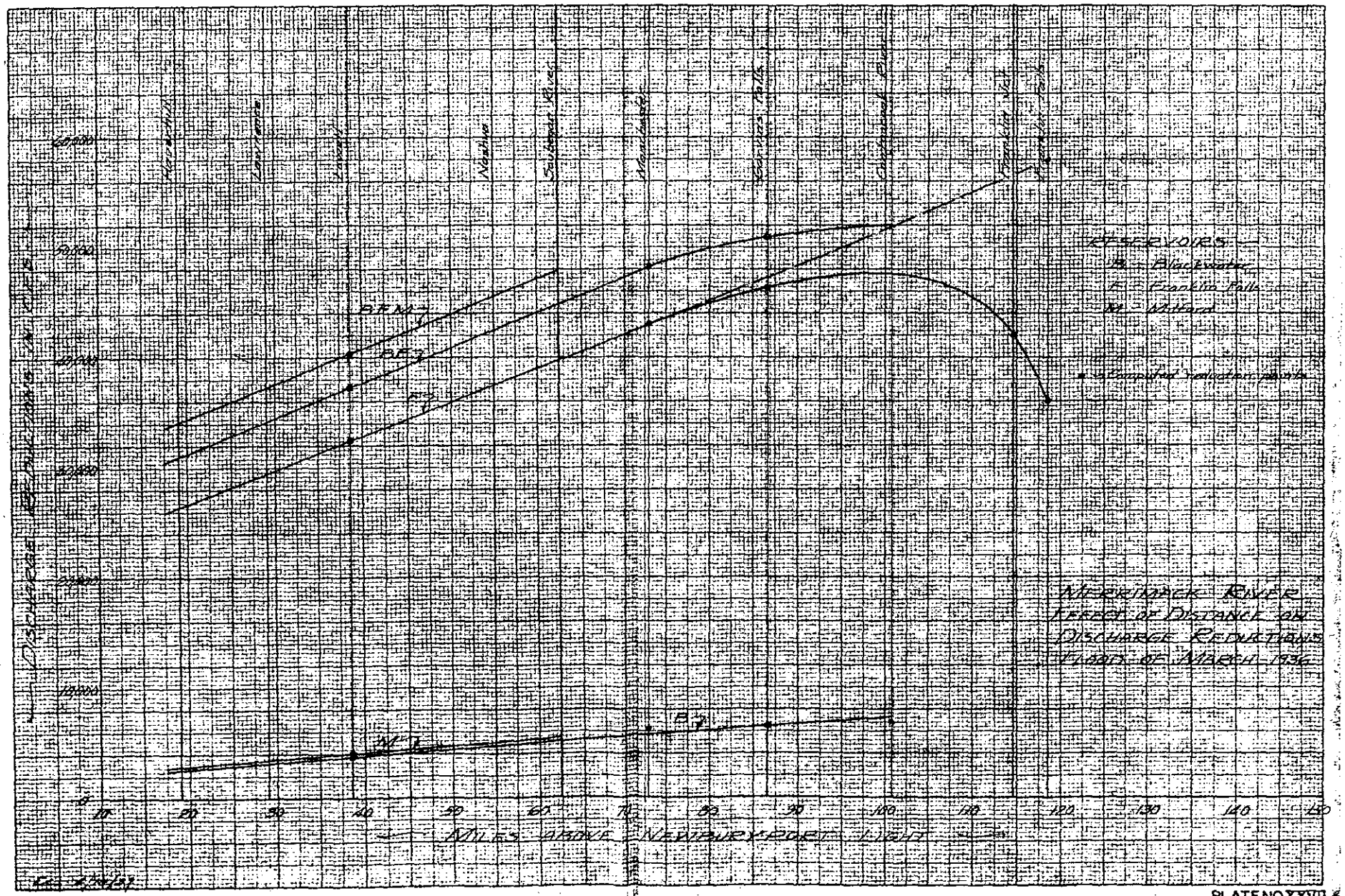
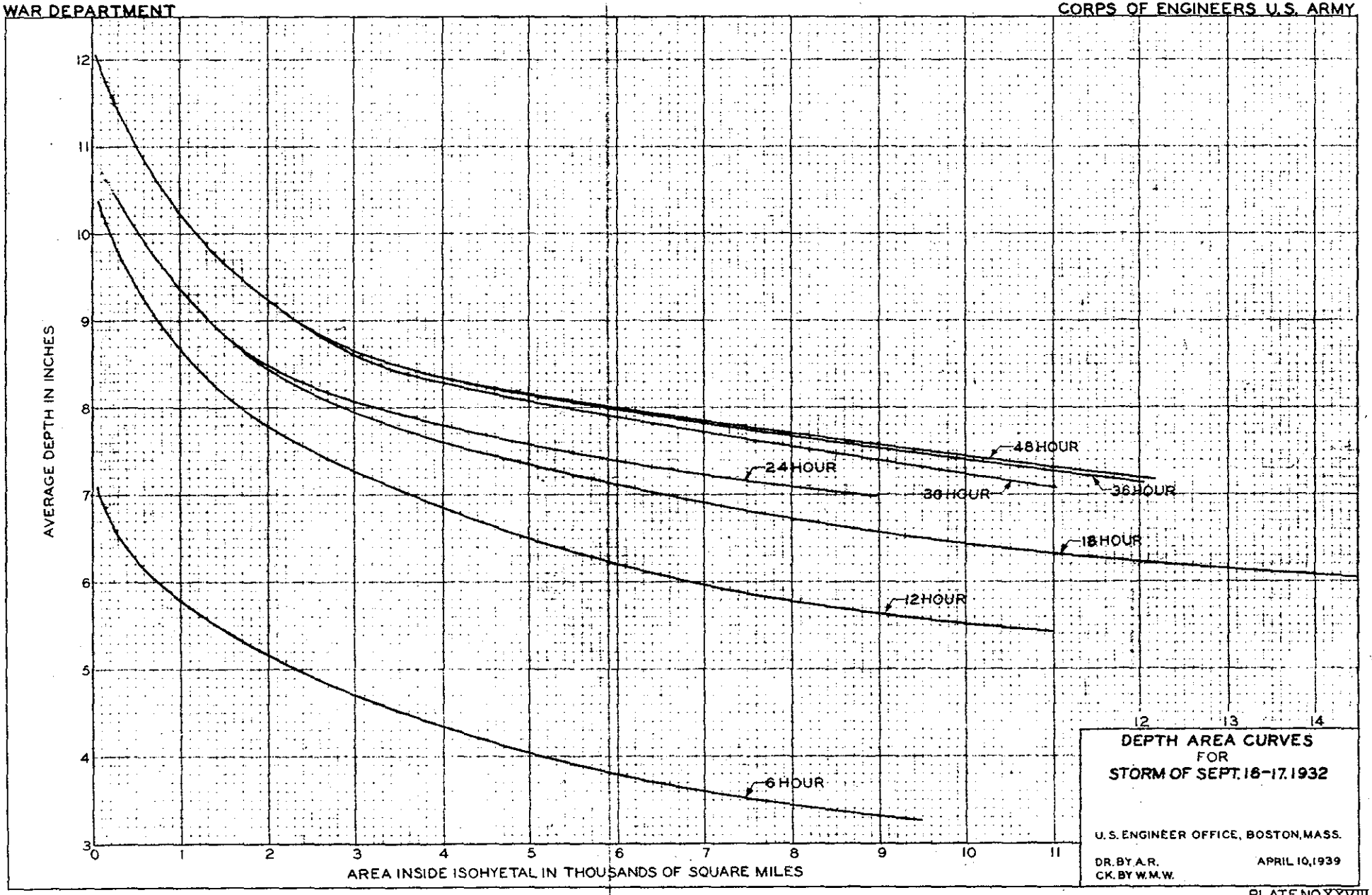


PLATE NO. XXVII

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



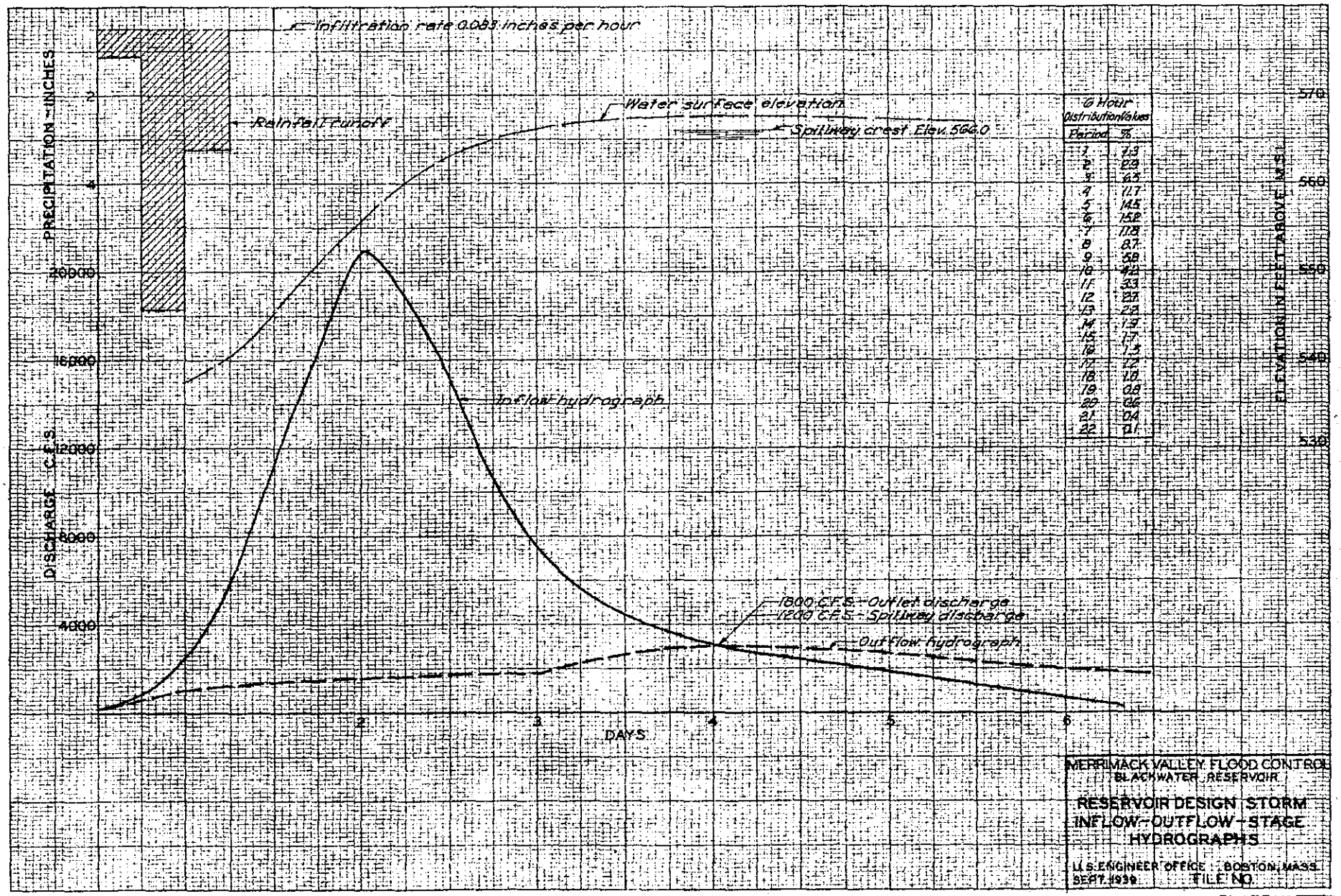
DEPTH AREA CURVES
FOR
STORM OF SEPT. 16-17. 1932

U. S. ENGINEER OFFICE, BOSTON, MASS.

DR. BY A.R.
CK. BY W.M.W.

APRIL 10, 1939

PLATE NO. XXVIII.



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR

RESERVOIR DESIGN STORM
INFLOW-OUTFLOW-STAGE
HYDROGRAPHS

U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XXIX

REVISIONS

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR -
MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX A (Revised Dec. 16, 1939)

HYDROLOGY OF THE BLACKWATER RIVER DRAINAGE BASIN

Part I - The Spillway Design Flood

1. Reference.- Reference is made to Engineer Bulletin, R.& H. No. 9, 1938, subject, "Spillway Capacities," which directs, in paragraph 19, that a hydrology report will be submitted to the Office of the Chief of Engineers for approval as the first step in the final design of a project.

2. Project Description.- The Blackwater dam site is located on the Blackwater River, a tributary of the Contoocook River. The dam is approximately 8-1/2 miles above the mouth of the river in the village of Swetts Mills in Webster township, N.H. The reservoir controls a drainage area of 127.5 square miles, has an area at El. 566 of 3,140 acres, and a storage capacity of 46,000 acre-feet, equivalent to 6.8 inches run-off over the drainage area. The initial project, for flood control only, proposes use of the reservoir as a retarding basin with fixed outlet capacity, consisting of one gated and one ungated outlet, total capacity 2,000 second-feet at El. 566. Two additional gated outlets are available if desired to reduce the time of emptying the reservoir. The concrete overflow spillway is 240 feet long, crest at El. 566, and maximum height of 65 feet.

3. Basin Characteristics.- The drainage basin of the Blackwater River above the dam site is approximately 19 miles long, with a maximum width of about 12 miles. The river originates on comparatively steep mountain slopes with rapid run-off. The three headwater tributaries, comprising about one-half the total drainage area, combine in the two-mile reach above Potter Place, about 20 miles by river above the dam site. The total fall in the reach to the dam site is 100 feet, 40 feet of which are in the two-mile reach near West Salisbury; hence in the remaining 18 river miles the drop is about 60 feet, or about 3 feet per mile. The main valley is about 15 miles long and provides considerable valley storage, particularly in the reach below West Salisbury, that is reflected in the distribution values. Lakes, ponds, and swamps comprise about 8 square miles, or over 6% of the drainage area.

4. Stream Flow Data.- A United States Geological Survey stream gaging station is located on the Blackwater River near Webster about two miles downstream from the dam site and has been

in operation since October 1934. It measures the flow from a drainage area of 129 square miles, only 1.5 square miles more than the drainage area at the proposed dam site. Records at this station have been used as the basis for stream flow data and studies of the distribution values. Staff gage readings and discharge measurements have been taken by this office at the Swetts Mills dam site to establish a tailwater rating curve and correlated to discharges recorded at the U. S. Geological Survey station. Discharge records based on one or two daily gage readings have been obtained by the U. S. Geological Survey further downstream near Contoocook (drainage area 134 square miles) from 1918-1920 and 1927-1934.

5. Precipitation Stations and Records.- The only precipitation station in the Blackwater Basin is a non-recording station established by this office at South Danbury in January 1937. The records obtained at this station are considered exceptionally good for this type of station. The U. S. Weather Bureau has maintained for many years stations adjacent to the watershed. Stations used for this study are shown on plate 13 and on plate 14. The only recording rain gage applicable to the Blackwater River Basin is located at Concord, N.H., about 12 miles distance from the dam site. The mass curves of precipitation for the non-recording gages were drawn with and conforming to the Concord recording rainfall data.

6. Distribution Graph.- The distribution values for the inflow hydrograph for Blackwater Reservoir were based on an analysis of the September 1938 flood. This flood had a peak value of 6,880 c.f.s. and is by far the maximum flood of record uninfluenced by snow run-off. The March 1936 flood, with a peak of 11,000 c.f.s., is the maximum of record but was primarily due to heavy snow melt; hence, because of uncertainties in required assumptions to utilize this flood for distribution values, it was not considered suitable for a check on the 1938 flood distribution values. A search for floods recorded at the present U. S. Geological Survey gaging station not affected by snow run-off gave 9 minor rises, with peak values less than 800 c.f.s. At the former U.S. Geological Survey station, with one or two daily readings, the maximum recorded discharge was 2,250 c.f.s., with possible backwater effect from the Contoocook River. A preliminary study of these minor floods showed peak distribution values appreciably lower than those from the 1938 flood due to the large effect of valley storage and regulation. The results could not be considered a check. The hydrograph recorded at the U.S. Geological Survey gage can be considered an outflow from the reservoir area without appreciable correction. In order to obtain an inflow hydrograph, this flood hydrograph was routed backwards through the valley storage of the reservoir site. The hydrographs are shown on plate 15.

7. Plate 14 gives the mass curves of precipitation for the stations in and adjacent to the Blackwater Basin for the flood of September 1938. Six-hour rainfall values were obtained from these curves and distributed over the basin using Thiessen's weighting. The total weighted rainfall for the storm is 7.81 inches in 72 hours. The flood hydrograph, after deducting base flow, showed a run-off of 4.64 inches. Thus, the total infiltration and other losses amounted to 3.17 inches. The average rate of these losses was computed, based on weighted hourly rainfall and total losses, to be 0.087 inch per hour. The rainfall and run-off are shown in bi-hourly values on plate 15. Six-hour distribution values were obtained for this inflow hydrograph, using six-hour rainfall values. The procedure and values used are shown on plate 16. The reconstructed hydrograph, using the derived distribution values, shows a satisfactory check with the original hydrograph. The unit hydrograph, based on one inch of run-off occurring in a period of six hours, is shown in plate 17. When this unit graph was used to derive the computed spillway flood, the resulting peak inflow gave a Myer rating of only 2830. Because of the comparatively low peak of the flood used in deriving the distribution values and the probably large effect of valley storage on the values, it was decided to increase the unit graph peak so that the resulting computed spillway flood would have a peak inflow with a Myer rating of at least 4000. The time of lag was reduced to maintain a reasonable relation to the higher peaked distribution values. It was found that reducing the time of lag tended to decrease the surcharge resulting from a flood of given volume and peak. Therefore, a time of lag of 16 hours was selected rather than a lesser value. The revised unit graph adopted is shown as a solid line on plate 17.

8. The following terms are used, as defined in Engineer Bulletin, R. & H. No. 9, 1938: (a) Reservoir Design Flood; (b) Computed Spillway Flood; (c) Spillway Design Flood; (d) Freeboard; (e) Freeboard Storage; (f) Surcharge; (g) Surcharge Storage; (h) Wave Height; (i) Wind Setup.

9. Maximum Storm.- The rainfall data for determining the maximum storm has been obtained from values furnished the Providence Office by the hydro-meteorological section of the U. S. Weather Bureau. The data are shown on plate 18. Instead of the value shown for 127.5 sq. mi. area on the six-hour curve on plate 18, a higher value plotted as a point on plate 18, was used upon recommendation of the hydro-meteorological section of the Office, Chief of Engineers. Comparison was made of the 24-hour and 48-hour depth-area curves from this storm with those for the total September 1932 and October 1903 storms and the 48-hour envelope curves developed by the Pittsburgh District Office, and were found to give materially higher values of rainfall for a 127.5 sq. mi. drainage area. Detailed study for this size drainage area of maximum storm data based on actual maximum storms of record (com-

parable to that obtained for the Franklin Falls project) is not available; hence, no absolute comparison can be made of the relative flood magnitude of summer and of spring storms with snow run-off. However, it is believed that for the small drainage area of the Blackwater River the much higher intensity of summer storms will prove to give appreciably greater peak values.

10. Computed Spillway Flood.- The computed spillway flood was based on the derived distribution values and on the rainfall curves shown on plate 18 and is shown on plates 19 and 20. This is a summer storm and consequently an assumed minimum infiltration rate of 0.083 inch per hour, or 0.5 inch per six-hour period was adopted. This is less than the average rate of 0.087 inch per hour determined from the September 1938 flood, where conditions of excessive rainfall during July and the three weeks in September prior to the flood were productive of minimum infiltration rates. A base flow of 2 c.f.s. per square mile was added to the flow run-off. Data pertaining to this flood are briefly summarized as follows:

Rainfall	-	19.4 inches in 48 hours
Run-off	-	15.8 inches
Volume	-	110,600 acre-feet (including base flow)
Peak inflow	-	49,300 c.f.s.
Peak outflow	-	32,200 c.f.s.
Maximum pool elevation	-	576.8

Determination of Spillway Design Flood

11. Reservoir Operation Assumptions.- It is assumed that the reservoir will be filled to normal maximum pool elevation of 566 feet M.S.L., which is the crest of spillway, at the beginning of the spillway design flood. The outlets are assumed to be inoperative.

12. Spillway Rating Curve.- The spillway rating curve (plate 21) was computed by the weir formula $Q = CLH^{3/2}$, where values of "C" for an unsubmerged Ogee section were taken from 3.0 to 3.8 at maximum head.

13. Method of Routing.- As the computed spillway flood was based on distribution values for inflow to the reservoir, the flood was routed through the reservoir using the gross storage. (Reference is made to appendix F of the "Survey Report for Flood Control, Merrimack River," dated April 1, 1938, for a detailed discussion of the reservoir routing used by the Boston Office.)

14. Spillway Design Flood.- The computed spillway flood was routed through the reservoir to obtain the reservoir discharge and the maximum water surface elevation. The inflow ordinates of the computed spillway flood were then increased 50 and 100 per cent and similarly routed through the reservoir. The data derived from these three routings are shown graphically on plate 22, where the per cent of computed spillway flood is plotted, (a) against the pool elevation in feet above mean sea level, and (b) against the peak inflows and outflows. After carefully considering (see following paragraph) all the factors itemized in the Engineer Bulletin, R. & H. No. 9, 1938, subject: "Spillway Capacities," paragraph 11, it was decided to adopt, as the "Spillway Design Flood" for the Blackwater Dam, the computed spillway flood plus a factor of safety of 35 per cent. The resulting spillway design flood is shown on plate 23.

15. Discussion of Factor of Safety.- In selecting 35 per cent as the factor of safety to be applied to the computed spillway flood, the following items, as enumerated in the Engineer Bulletin referred to in preceding paragraph, were considered:

a. The long-time rainfall records are too few to cover adequately all large storms of record in this district. Results of the storm studies now being made by this office, and other data as outlined in paragraph 9 above, show that the spillway design storm used gives rainfall values materially in excess of the maximum storms experienced. The design storm, based on data available in this office, is believed to give maximum rainfall values.

b. The maximum rainfall values used as shown on plate 18 for 127.5 square miles are about twice those for a like area in the September 1932 storm and exceed by a greater proportion the rainfall values for smaller drainage areas. The maximum point rainfall values available in this office were obtained from unofficial records. These values are 10 inches in about two hours at Peterboro, N.H., during the September 1938 storm and 11 inches in about three hours obtained during a cloudburst August 1939 at Baldwin, Maine. These values are over 50 per cent less than those shown for 3-hour rainfall on a one-square-mile drainage area. Hence, rainfall values given on plate 18 are greater than those recorded in information available in this office. There appears to be little possibility that they will be exceeded.

c. The flood of September 1938 makes available an accurate determination of discharge quantities and reasonably accurate rainfall data. This is the only summer flood suitable for study, and with the excessive rainfall prior to the flood, should give values of infiltration closely approaching the minimum. The analysis of the September 1938 flood (plate 15) indicated a rate of infiltration of 0.087 inch per hour. A lower value of 0.5 inch per 6-hour period (0.083 inch per hour) was used in the computed spillway flood. Expressed in terms of per cent run-off, this is equivalent to 88 per cent run-off for the maximum 24-hour precipitation.

d. The unit hydrograph (plate 17) and distribution graph (plate 15) are based on an analysis of the September 1938 flood, the second largest flood of record. Study of the values obtained indicated the desirability of peaking the values as described in paragraph 7. The computed spillway flood peak value is approximately 7 times that of the 1938 flood. However, the surcharge storage of 47,000 acre-feet available for the spillway design flood, with total volume of 150,000 acre-feet, is believed to minimize the inaccuracies inherent in the determination of the distribution values and the extrapolation of these values to a flood with peak value about 9-1/2 times that of the 1938 flood.

e. Errors in routing the design flood through the reservoir because of inaccuracies of assumed storage volume, backwater curves, and time of water travel are believed to be negligible. As the assumption is made that the reservoir is full at the beginning of the flood, the time of water travel is practically instantaneous through the reservoir. The spillway flood is computed as an inflow hydrograph and consequently consideration of the effect of valley storage in the reservoir was not required. The capacity curve of the Blackwater Reservoir is based on a topographic survey of the reservoir from which the values used for surcharge storage are obtained. There should be no appreciable error in the storage capacity curves or in the resulting reduction to the inflow peak obtained by routing the spillway flood through the surcharge storage.

f. Whether or not the outlet conduits are gated does not affect the criterion used, namely that during the duration of the spillway flood the outlets are

assumed inoperative. Should the outlets actually be used for discharges during the spillway flood, the peak surcharge would be only slightly reduced. There is the possibility that the reservoir may be developed for power in the future. If this is done, the present proposal is to raise the crest of spillway to El. 584 and lengthen the spillway in order to reduce the surcharge. This will not change the basic spillway design storm or conditions, except to provide additional surcharge storage for a given increment of spillway surcharge.

g. The spillway is a straight overflow Ogee section. The spillway discharge rating has been computed with conservative values of "C" and it is believed that the spillway discharge capacity will actually exceed the computed values.

h. The freeboard storage in the Blackwater Reservoir is a considerable item. Between El. 579 and top of dam at El. 584 there are 22,000 acre-feet of storage, equivalent to 3.2 inches. There is a definite factor of safety against overtopping of the dam that may be attributed to this freeboard storage and spillway capacity, requiring a flood over twice the computed spillway flood to overtop the dam.

16. Summary.- In view of the items discussed in the preceding paragraphs, it is believed that a 35 per cent factor of safety applied to the computed spillway flood is adequate. The hydrograph of this flood is shown on plate 23 with the outflow-stage hydrographs and reservoir elevations. Data concerning this flood are summarized as follows:

Selected Spillway Design Flood
(Computed Spillway Flood Plus 35 Per Cent)

Volume = 148,300 acre-feet (including base flow)

= 22.0 inches of run-off from a 48-hour period of rainfall

Peak inflow = 66,500 c.f.s.

Peak outflow = 42,800 c.f.s.

Maximum pool elevation 579.0 ft. above M.S.L.

Freeboard 5.0 ft.

Part II - Reservoir Design Flood

17. Maximum reservoir capacity is governed by the physical limitations of the dam site and by the size of the maximum probable flood. The former is determinable from the field surveys, the latter is not definitely determinable because of limited length of adequate discharge records. Another factor in the physical limitation to storage is the outlet discharge, governed by channel capacity and related to the storage proposed and reservoir design storm used. It is desirable to discharge from the outlets a flow not exceeding channel capacity or limiting the flow to that value which will not cause flooding on the tributary. This item of channel capacity is not important on the Blackwater River from the standpoint of flood damage in the reach from the dam to the Contoocook River. The greater the storage provided for the given storm, the smaller the outlet discharge and the greater the flood reduction obtained downstream. However, there is a practical limitation to the reduction of outlet discharge in that a flood control reservoir should be emptied in a reasonable time to provide for the possible condition illustrated by the 1936 flood where two major storms produced peak floods within a week of each other.

18. Related to all of the above factors is the economic consideration limiting the cost of the storage capacity to that which will give the greatest ratio of benefits to costs.

19. The reservoir design flood formerly used was based on economic consideration wherein it appeared desirable to limit the size of the reservoir to control a flood produced by a rainfall of about 100-year frequency, and also to empty the reservoir in a reasonable length of time. To arrive at such a storm, long-time rainfall records at Concord were studied. It was found from these records that a 100-year rainfall of 3-days' duration amounted to about 8 inches. With this storm a high run-off factor of 90 per cent was applied. In order to justify this high run-off factor, a 3-day storm of 1-1/2 inches of rainfall per day was added prior to the 100-year 3-day storm. This gave a flood volume that, in its effect on reservoir capacities, was about equivalent to the 1936 flood, the maximum flood of record. The flood obtained from these assumptions, however, must be considered as one of less frequent occurrence than once in 100 years because of the assumptions made of the 3-day prior rainfall and the high run-off coefficient. This flood, when routed through the reservoir with an outlet discharge of about 1,800 c.f.s., gave a spillway lip or maximum pool elevation of 566 feet.

20. An approach to the maximum probable flood may be had by consideration of the maximum available storm of record. Recent study of recorded maximum storms show that apparently the greatest storm of record in New England was that of September 1932, with principal center at Westerly, Rhode Island. This storm compares in magnitude with others outside of New England that are considered as possible of occurrence in New England. This office has detailed information on the 1932 storm, and it is considered as a rational basis for computation of a reservoir design flood approaching the maximum probable flood. Utilizing this flood with the most severe condition of run-off, comparable with that obtained in the 1938 flood, gives a severe criterion for selection of reservoir capacity. Plate 28 shows the depth-duration curves of the 1932 storm used for deriving the values of rainfall, while plate 29 shows the constructed inflow hydrograph and the resulting outflow-stage hydrographs using the revised maximum outlet discharge of 2,000 second-feet at El. 566.

21. This storm produces an extremely high peak with moderate volume. When routed through the reservoir, the assigned storage capacity was found to be sufficient to control the flood, except for a moderate spillway outflow of 1,200 c.f.s. The rare frequency when this small flow in excess of the conduit capacity will occur is considered a negligible factor. Hence, it is believed that the flood based on the 1932 storm is a reasonable criterion for a reservoir design flood based on summer rainfall conditions.

22. The March 1936 flood, in most cases on the Merrimack Basin, exceeded in peak value, and definitely in volume, any flood of record. Since, in reservoir flood design, volume is of primary importance, reservoir design in the Merrimack Basin must recognize the spring flood as the possible governing criterion. Storage provided in the Blackwater Reservoir is found to be ample to control the 1936 flood with the proposed outlet capacity. (See plate 24.)

23. Study of all the factors involved in consideration of the control of the Blackwater River floods led to the choice of 46,000 acre-feet of flood control storage. The possibility that there may be some excess flood control storage in the Blackwater Reservoir should be considered a desirable condition in connection with the comprehensive scheme of flood control on the Merrimack to increase the effectiveness of the combination.

DEFINITE PROJECT REPORT FOR BLACKWATER RESERVOIR -
MERRIMACK RIVER BASIN FLOOD CONTROL

APPENDIX B (Revised Dec. 16, 1939)

HYDRAULICS

1. The hydraulic design of the Blackwater flood control dam presents no unusual features. The dam will be built in two stages, initially for flood control only and subsequently raised to provide for flood control and power storage, hence selection of the outlet capacities required adjustment so that the total reservoir outflow during a flood would not exceed the design discharge in either development. Since it will be practicable to operate the power plant of the final project during floods with a discharge of about 1,000 c.f.s., consideration had to be given this discharge in providing gated capacity that would permit operation to maintain a total reservoir outflow not exceeding the design outflow. Excess gated outlet capacity was desirable in order to expedite emptying the reservoir after the flood. Also, it is desirable to keep the gate sizes the same. After consideration and correlation of the foregoing, a design outflow of 2,000 c.f.s. was selected. This is provided in the initial development with one 3'-6" x 6'-5" ungated outlet and one 3'-6" x 5'-3" gated outlet. Two additional 3'-6" x 5'-3" gated outlets are to be installed initially but not used for flood regulation. These additional outlets are available, however, for use in decreasing the time required to empty the reservoir after floods. In the ultimate development the ungated outlet will be closed off and no longer used. The design discharge of 2,000 c.f.s. will then be attained at El. 584 by using two of the three gated openings. The third gated outlet is then available for additional capacity for emptying purposes. Partial gate opening will not be required either initially or ultimately under this arrangement. Also, in the ultimate plan, the outflow can be held to 2,000 c.f.s. with the power plant in operation by using only one flood control outlet. No stilling basin is required, the outlets discharging into a rock gorge entirely separate from the earth section of the dam. An Ogee free overfall concrete spillway 240 feet long is provided, the capacity being readily computed from the weir formula (see plate 21). The structure is founded on rock with a curved bucket for the high portion of the spillway to deflect the overflow parallel to the stream bed. The gorge below the spillway is narrow, with steep fall, and will pass the spillway design outflow peak without submerging the spillway crest. In order to prevent possible overflow of the narrow discharge channel, some enlargement

by excavation will be provided. The flood reductions at the dam site were obtained by reservoir routing of the flood hydrographs. The results are shown for the March 1936 flood, the flood based on the September 1932 storm, and the spillway design flood, on plates 24, 29, and 23, respectively.

2. Reductions to the flood at the dam site were carried downstream to the damage centers through Haverhill on the Merrimack River. The March 1936 flood, surpassing all other floods of record in the Merrimack Basin in magnitude and general extent, provides an excellent measure of the probable effectiveness of the reservoir. Downstream reductions were computed for the Blackwater Reservoir alone and in combination with the Franklin Falls Reservoir, and also in combination with the Franklin Falls Reservoir and the Contoocook River Flood Diversion Project. The Blackwater Reservoir, with 6.8 inches of storage, is entirely adequate for all minor floods or spring freshets. Its maximum effectiveness in reduction of large floods may best be gaged by its effect on the 1936 flood. The 1936 flood, as recorded at the U.S. Geological Survey gage near Webster, was routed through the reservoir. Plate 24 shows inflow, outflow, and stage hydrographs for this flood. Pertinent data concerning this flood are as follows:

1936 peak discharge	11,000 c.f.s.
Reduced reservoir peak discharge . . .	1,900 c.f.s.
Maximum pool elevation	560.5

3. The maximum capacities of the various outlets and the initial full pool elevation of 566 are as follows:

One 3'-6" x 6'-5" ungated -	1,120 c.f.s.
Three 3'-6" x 5'-3" gated -	880 c.f.s. each

Using these outlets as described in paragraph 1, the 1936 flood was routed through the reservoir. The outflow, reservoir stage and time required for emptying are shown on plate 24. Similar data for the flood based on the 1932 storm are shown on plate 29. The time of emptying from a full pool in the initial plan is 9 days. For the ultimate plan, using three gated outlets with a maximum capacity at El. 584 of 3,000 c.f.s., the time of emptying is about 10 days.

4. The effect of the Blackwater Reservoir in reducing the 1936 flood at two of the downstream damage centers, Manchester, N.H. and Lowell, Mass., on the Merrimack River, is shown by the hydrographs on plates 25 and 26. The same plates also show the discharge reduction credited to the Franklin Falls Reservoir (now under construction) and the combination of the Franklin Falls and Blackwater Reservoirs. It shows at these two points that

Blackwater Reservoir in combination with Franklin Falls adds about 5,000 c.f.s. to the peak reduction for the 1936 flood.

5. Plate 27 shows the effect of distance on the discharge reductions as applied to the flood of March 1936. These curves are based on reach-routing computations and are useful in determining discharge reductions at intermediate damage centers.

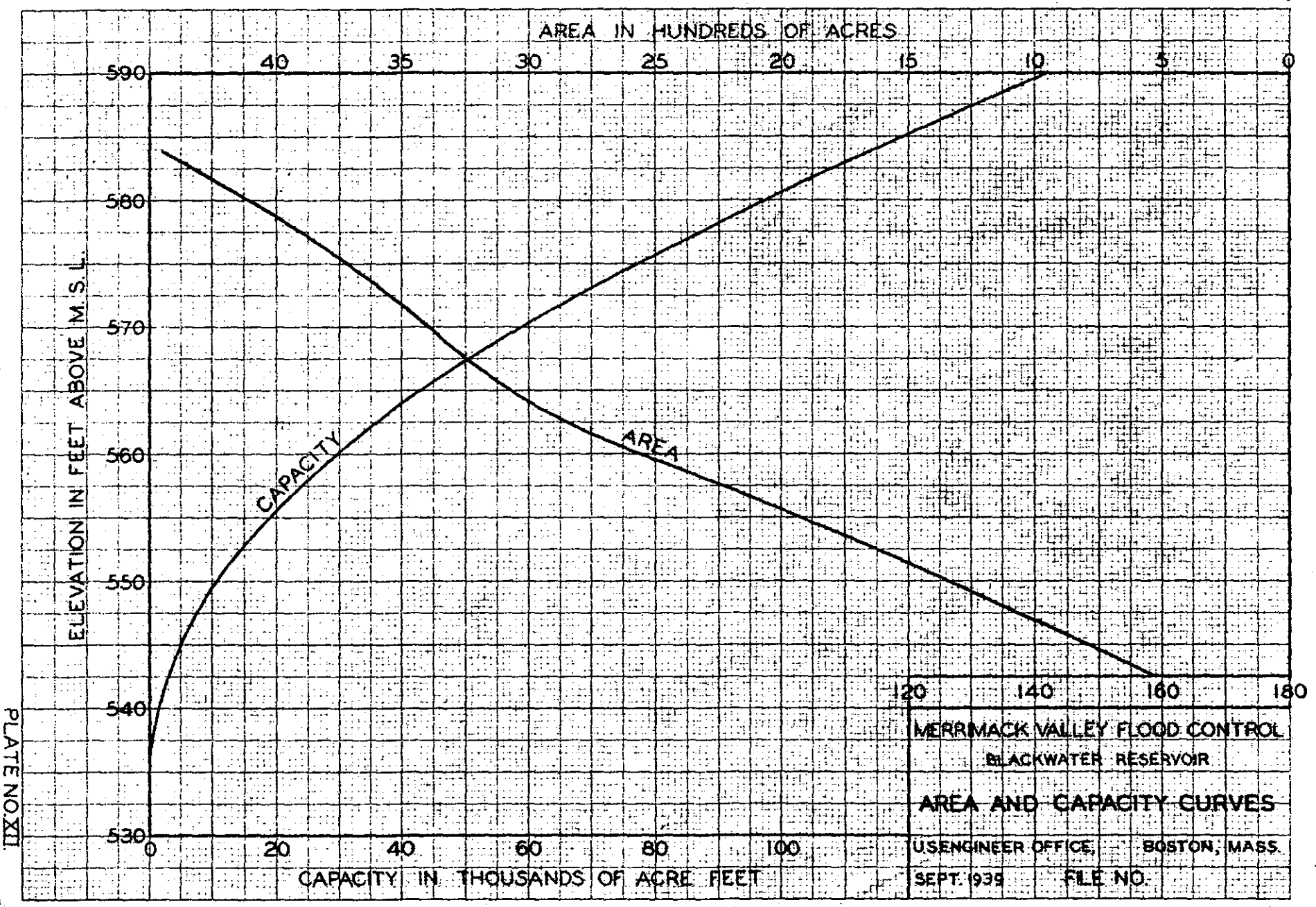

AREA IN HUNDREDS OF ACRES
40
35
30
25
20
15
10
5
0
590
580
570
560
550
540
530
ELEVATION IN FEET ABOVE M.S.L.
CAPACITY
AREA
0
20
40
60
80
100
120
140
160
180
CAPACITY IN THOUSANDS OF ACRE FEET
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
AREA AND CAPACITY CURVES
U.S. ENGINEER OFFICE, BOSTON, MASS.
SEPT. 1939
FILE NO.

PLATE NO. XII

PLATE NO. XIII

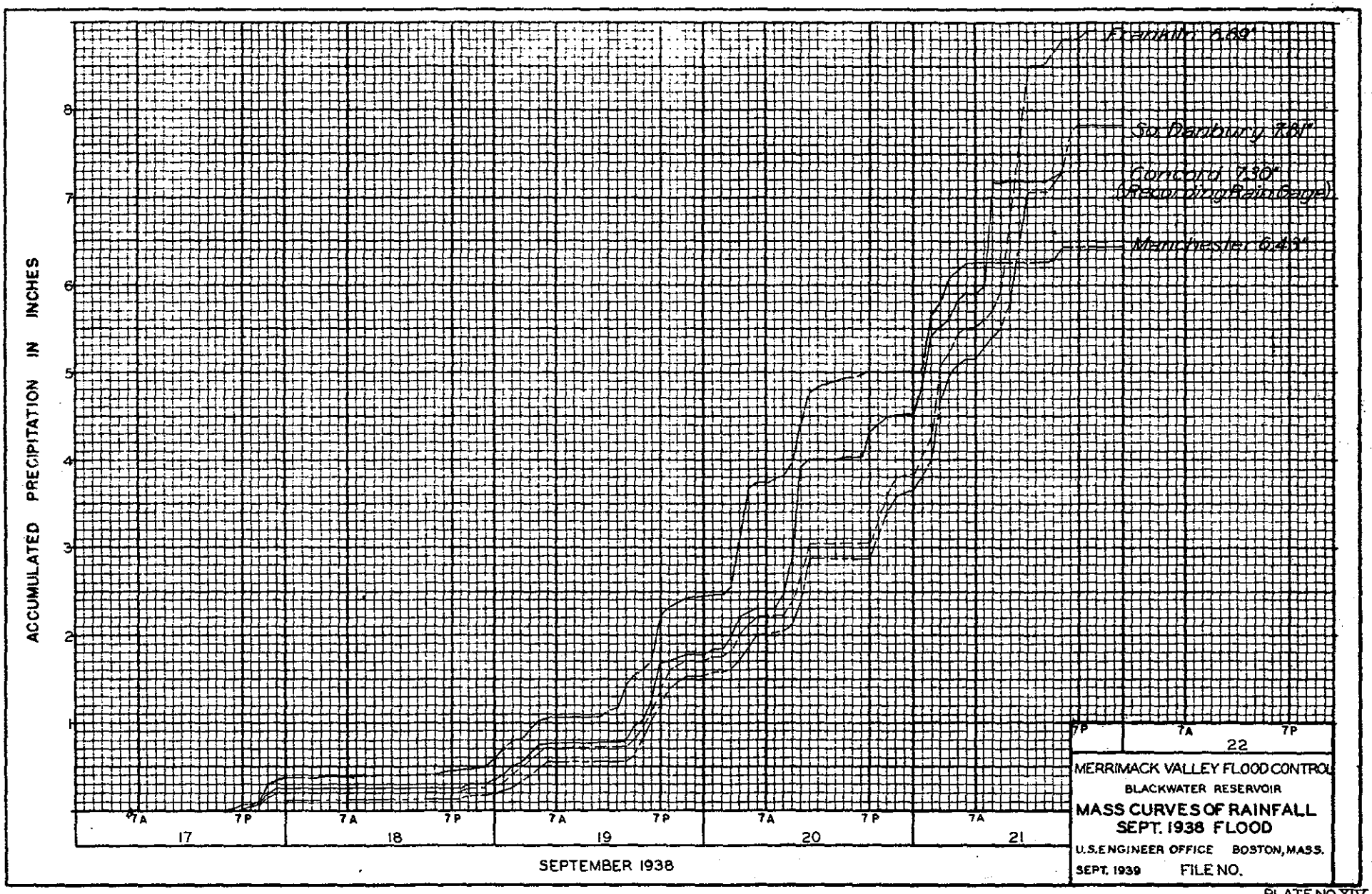
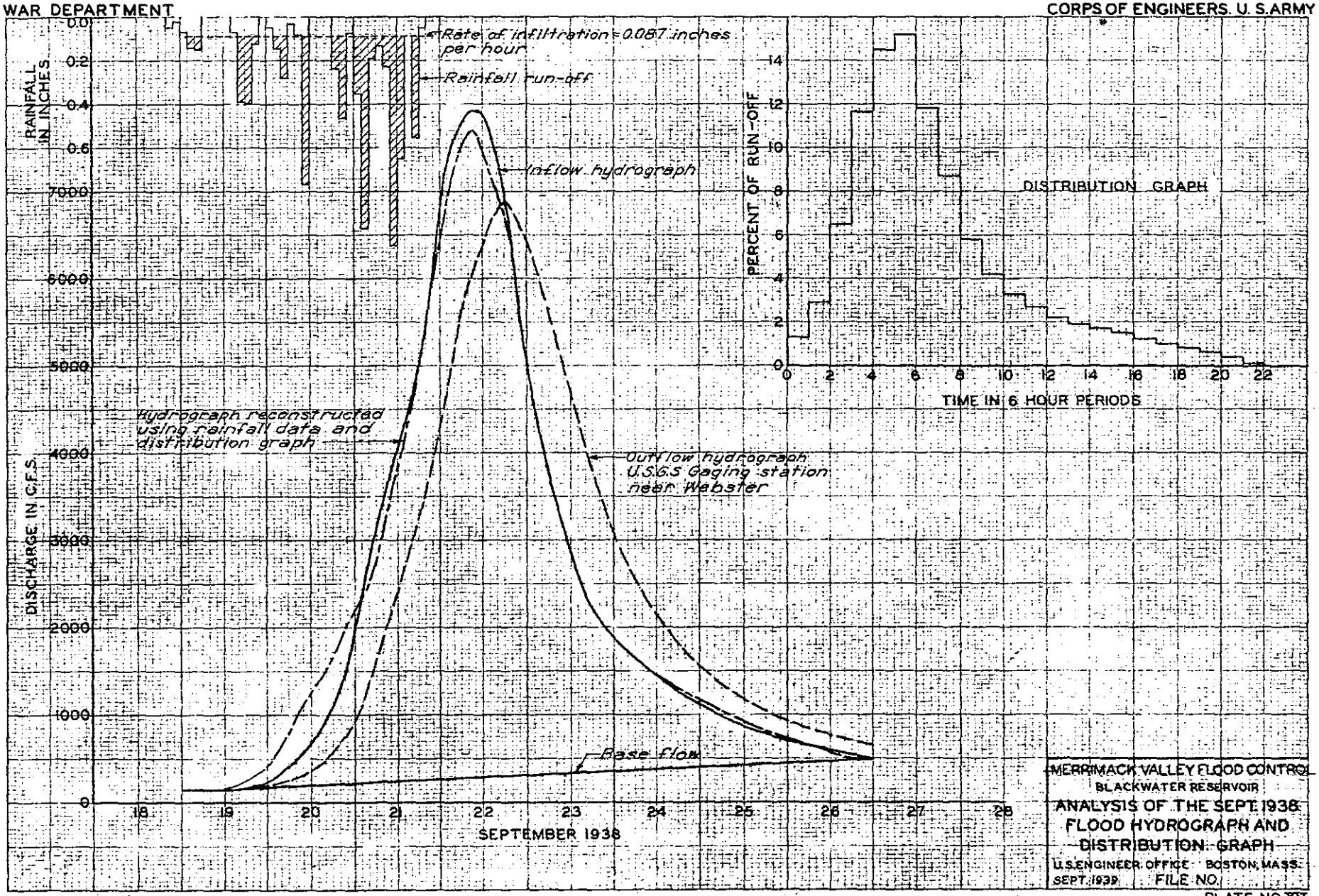

ACCUMULATED PRECIPITATION IN INCHES
1
2
3
4
5
6
7
8
Franklin 6.89"
So Danbury 7.81"
Concord 7.50"
(Recording Rain Gage)
Manchester 6.49"
7A
7P
17
18
19
20
21
22
SEPTEMBER 1938
MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
MASS CURVES OF RAINFALL
SEPT. 1938 FLOOD
U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939
FILE NO.

PLATE NO. XIV

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR

ANALYSIS OF THE SEPT. 1938 FLOOD HYDROGRAPH AND DISTRIBUTION GRAPH

U.S. ENGINEER OFFICE · BOSTON, MASS.

SEPT. 1939 FILE NO.

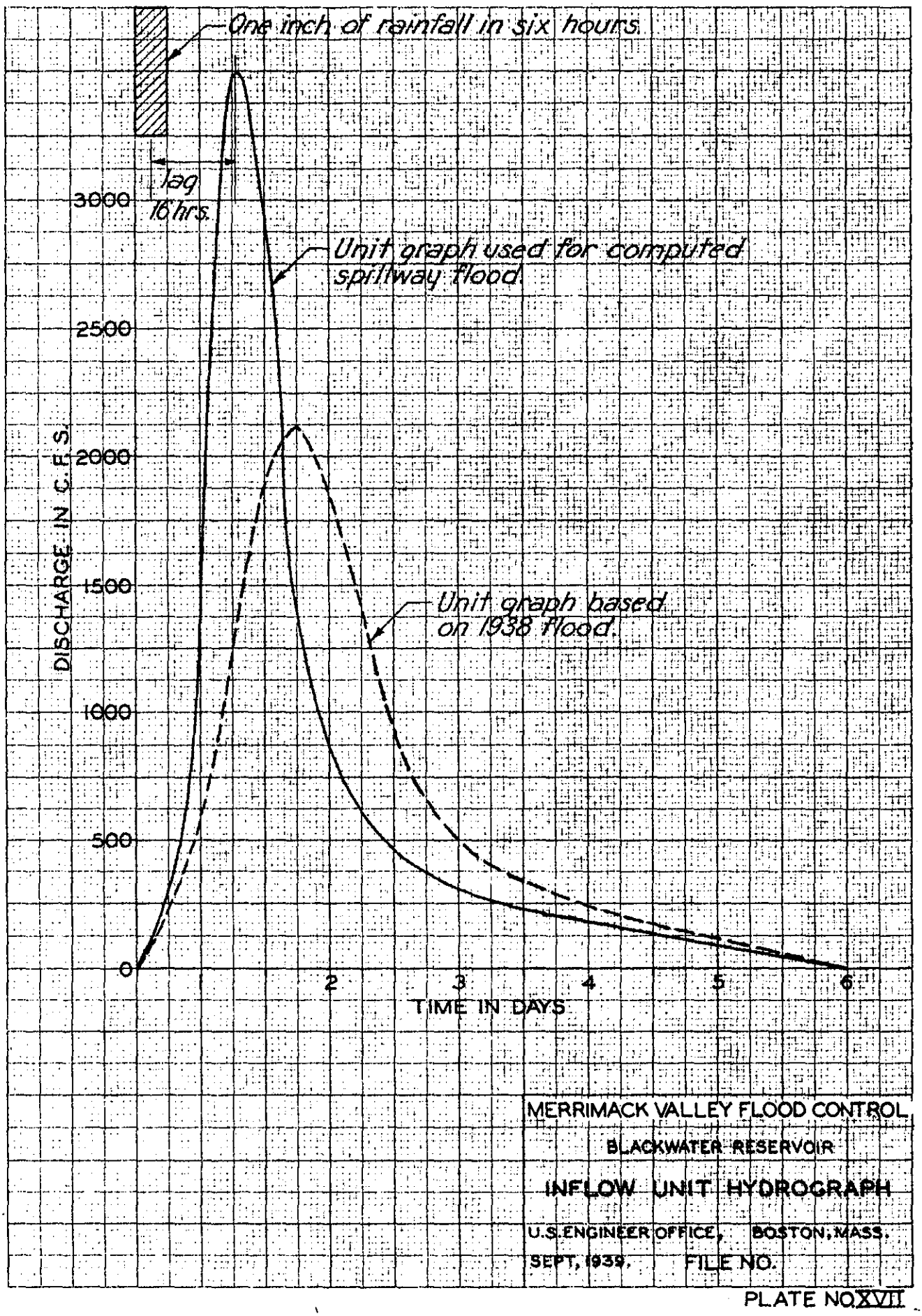
PLATE NO. XV

WAR DEPARTMENT
U. S. ENGINEER OFFICE, BOSTON, MASS.

Subject: Blackwater Reservoir
Computation: Derivation of Distribution Values from 1938 Flood
Computed by: E.C. Checked by: Date: 9/21/39
Page

Sept 1938	Runoff inches	W'td Runoff d.s.f.	Total Inflow Hydro. d.s.f.	Base Flow d.s.f.	Net Inflow Hydro. d.s.f.	0.39/0.39	1.57/0.39	1.04/0.39	0.45/0.39	0.60/0.39	0.14/0.39	0.45/0.39	Distrib Values	6 Hour Periods
19 N														
6P	0.45	1537	40	37	3							21		
M	0	–	50	40	10							46		
6A	0.14	478	82	43	39						6	104		
20 N	0.60	2049	137	46	91					28	14	186		
6P	0	–	217	49	168					62	32	231		
M	0.45	1537	363	52	311				21	139	58	242		
6A	1.04	3551	650	55	595			48	46	248	72	187		
21 N	1.57	5361	888	58	830		73	107	104	308	75	138	1.3	1
6P	0.39	1332	1140	61	1079	(18) 27	167	240	186	323	58	84	2.9	2
M			1460	64	1396	(40) 13	362	430	231	250	43	67	6.5	3
6A			1875	67	1808	(90) 116	650	534	242	185	29	52	11.7	4
22 N			1970	70	1900	161	805	560	187	123	21	43	14.5	5
6P			1875	73	1802	(200) 247	845	432	138	89	16	35	15.2	6
M			1500	76	1424	(210) 248	652	320	92	69	13	30	11.8	7
6A			1090	79	1019	162	482	214	67	57	11	26	8.7	8
23 N			825	82	743	(120) 136	322	155	52	46	9	23	5.8	9
6P			625	85	540	(80) 75	234	120	43	40	8	20	4.2	10
M			510	88	422	(58) 49	181	99	35	35	7	16	3.3	11
6A			438	91	347	(45) 38	149	80	30	31	6	13	2.7	12
24 N			388	94	294	37	121	70	26	26	5	9	2.2	13
6P			338	97	241	(30) 20	105	61	23	22	4	6	1.9	14
M			300	100	200	(26) 11	93	53	20	17	3	3	1.7	15
6A			262	103	159	(23) 3	81	45	16	12	2		1.5	16
25 N			230	106	124	(20) -3	68	37	13	8	1		1.2	17
6P			207	109	98	(17) -1	56	29	9	5			1.0	18
M			188	112	76	(14) 5	44	21	6				0.8	19
6A			175	115	60	(11) 12	32	13	3				0.6	20
N			155	118	37	(8) 9	20	8					0.4	21
6P			142	121	21	(5) 9	12						0.1	22
M			130	124	6	(3) 6								
	4.64	15845			15843		5548						100.0	

PLATE NO. XVI



MERRIMACK VALLEY FLOOD CONTROL

BLACKWATER RESERVOIR

INFLOW UNIT HYDROGRAPH

U.S. ENGINEER OFFICE, BOSTON, MASS.

SEPT, 1939. FILE NO.

PLATE NO. XVII

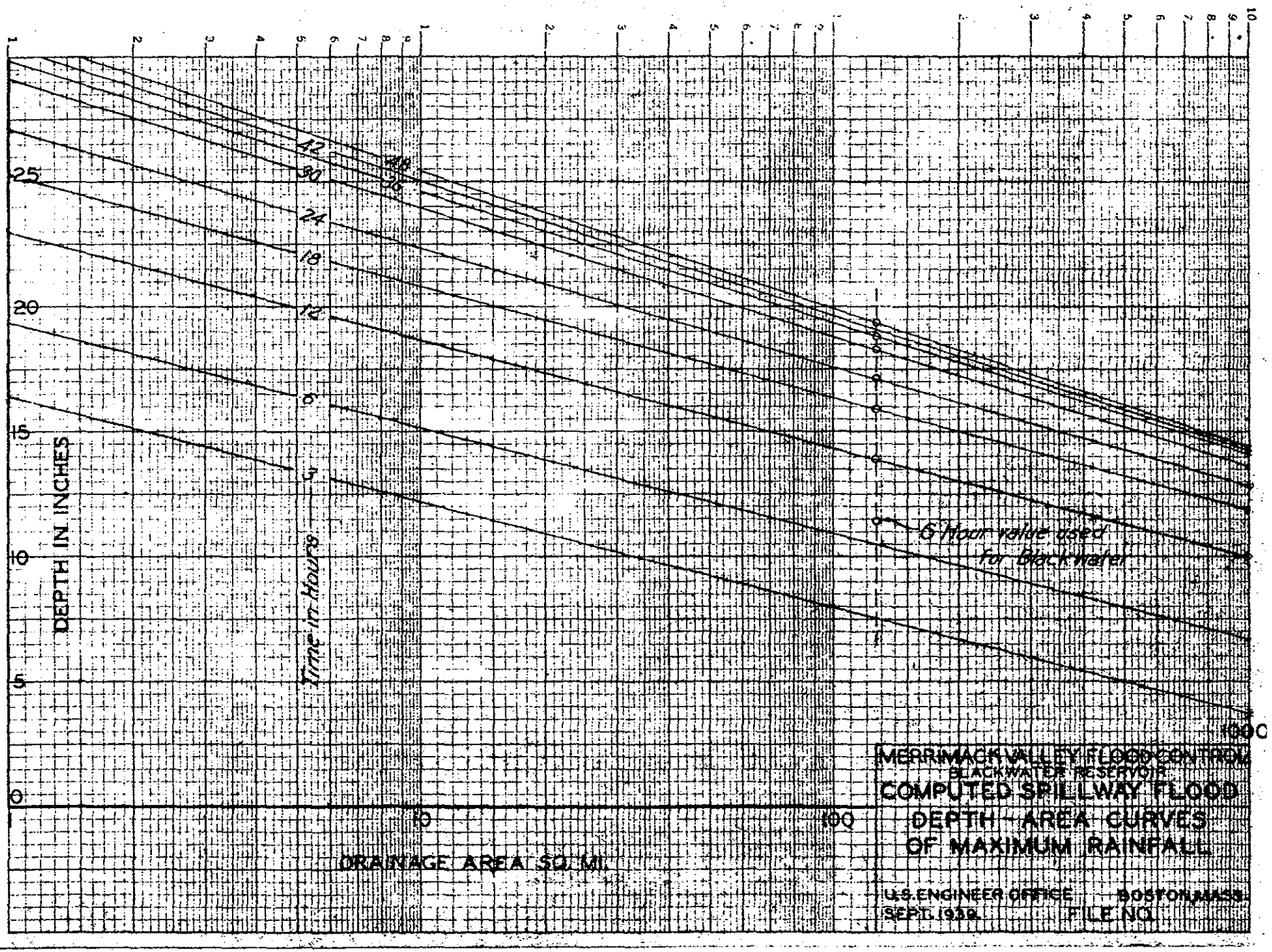


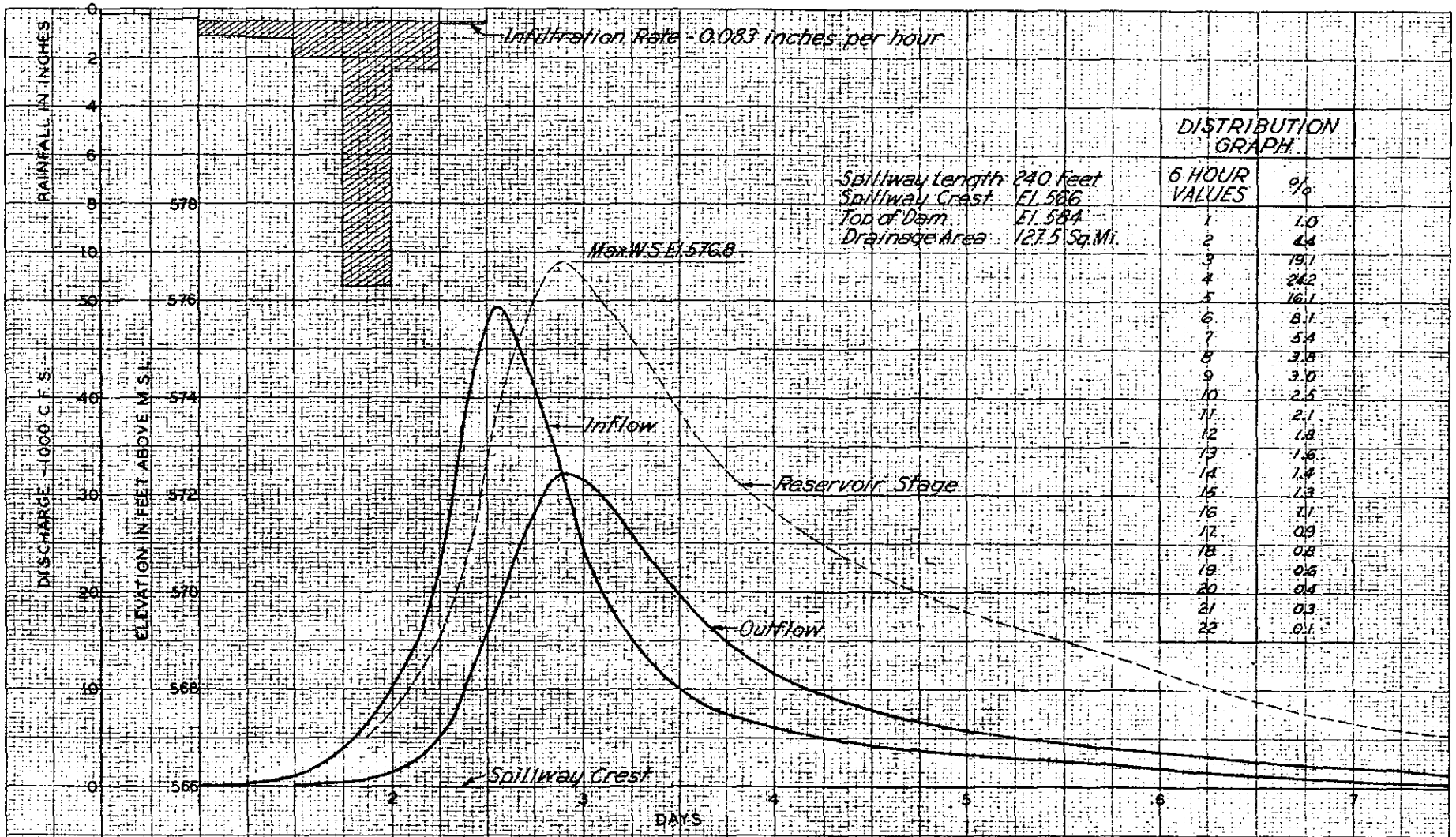
PLATE NO. XVIII

WAR DEPARTMENT
U. S. ENGINEER OFFICE, BOSTON, MASS.

Subject: BLACKWATER RESERVOIR
Computation: COMPUTED SPILLWAY FLOOD
Computed by: F.C.M. Checked by: W.M.W. Date: 11/13/39
Page

Period	Rainfall inches	Runoff [Infiltr. rate 0.083"/hr] inches	Run-off d.s.f.	Distribution Values %	Distributed Run-off – d.s.f. 1	2	3	4	5	6	Total Run-off d.s.f.	Total Run-off d.s.f./¼ day	Total Runoff with Base Flow – 2 cfs per sq. mi. d.s.f./¼ day
M	0.0	0.0											
6A	0.2	0.0											
1 N	0.4	0.0											
6P	1.1	0.6	2057	1.0	21						21	84	339
M	1.2	0.7	2400	4.4	91	24					105	460	715
6A	2.0	1.5	5143	19.1	393	106	51				550	2200	2455
2 N	11.4	10.9	37400	24.2	498	458	226	374			1556	6224	6479
6P	2.5	2.0	6860	16.1	331	581	982	1645	68		3607	14428	14683
M	0.6	0.1	343	8.1	167	386	1245	7140	302	3	9243	36972	37227
6A				5.4	111	194	828	9050	1310	15	11508	46032	46287
3 N				3.8	78	130	417	6020	1665	66	8376	33504	33759
6P				3.0	62	91	278	3025	1110	83	4649	18596	18851
M				2.5	51	72	195	2020	556	55	2949	11796	12051
6A				2.1	43	60	154	1422	371	28	2078	8312	8567
4 N				1.8	37	50	129	1120	262	19	1617	6468	6723
6P				1.6	33	43	108	935	206	13	1338	5352	5607
M				1.4	29	38	93	785	172	10	1127	4508	4763
6A				1.3	27	34	82	673	144	9	969	3876	4131
5 N				1.1	23	31	72	598	124	7	855	3420	3675
6P				0.9	19	26	67	524	110	6	752	3008	3263
M				0.8	16	22	57	486	96	5	682	2728	2983
6A				0.6	12	19	46	411	89	5	582	2328	2583
6 N				0.4	8	14	41	337	75	4	479	1916	2171
6P				0.3	6	10	31	299	62	4	412	1648	1903
M				0.1	2	7	21	224	55	3	312	1248	1503
						2	15	149	41	3	210	840	1095
							5	112	28	2	147	588	843
								37	21	1	59	236	491
									7	1	8	32	287
	19.4	15.8	54203	100.0	2058	2398	5143	37386	6874	342	54191	216804	223434

PLATE NO. XIX



DISTRIBUTION GRAPH

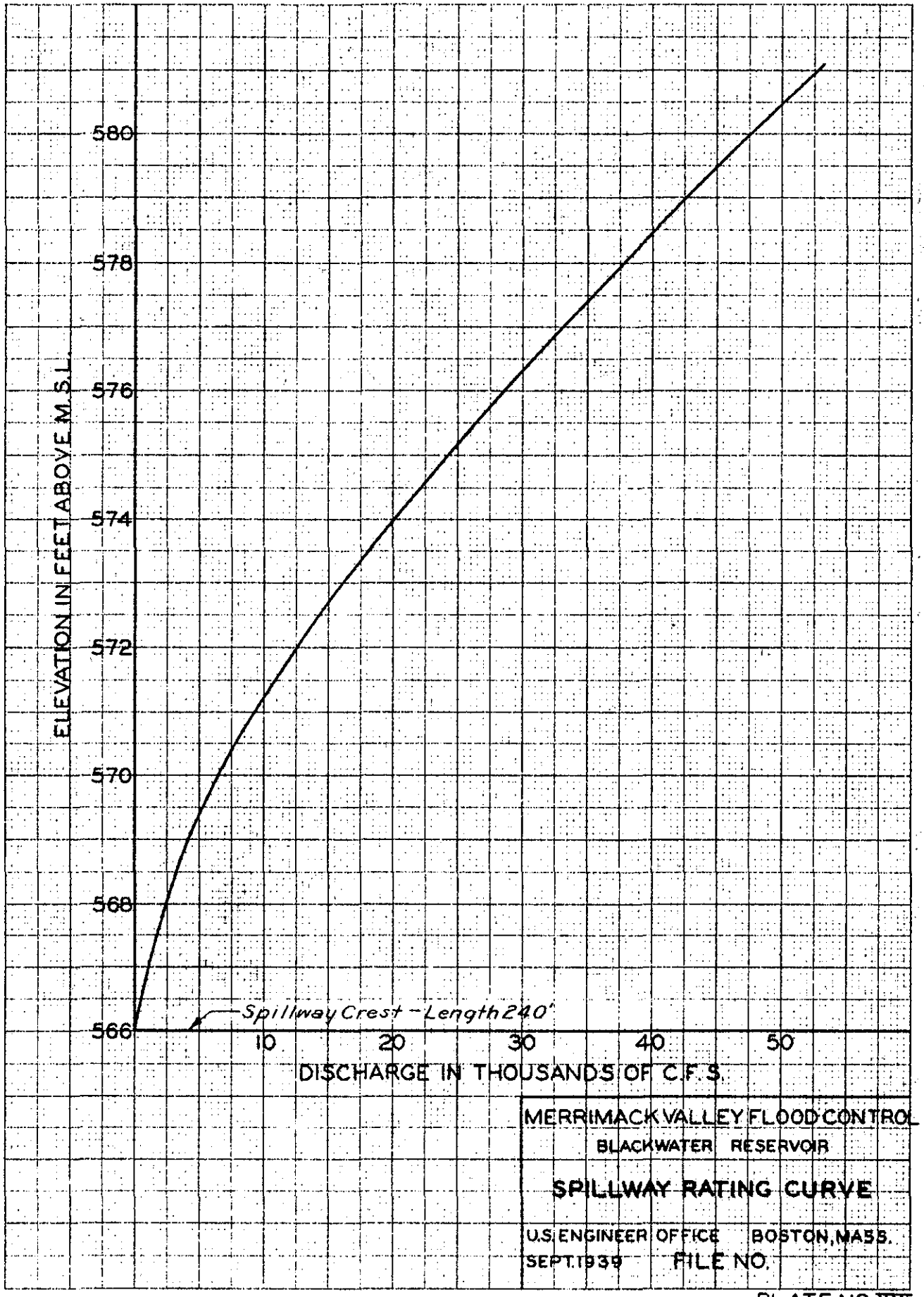
6 HOUR VALUES	%
1	1.0
2	4.4
3	19.1
4	24.2
5	16.1
6	8.1
7	5.4
8	3.8
9	3.0
10	2.5
11	2.1
12	1.8
13	1.6
14	1.4
15	1.3
16	1.1
17	0.9
18	0.8
19	0.6
20	0.4
21	0.3
22	0.1

MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR

COMPUTED SPILLWAY FLOOD
INFLOW - OUTFLOW
STAGE HYDROGRAPH

U.S. ENGINEER OFFICE BOSTON MASS.
SEPT. 1939 FILE NO.

PLATE NO. XX



MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR

SPILLWAY RATING CURVE

U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XXI

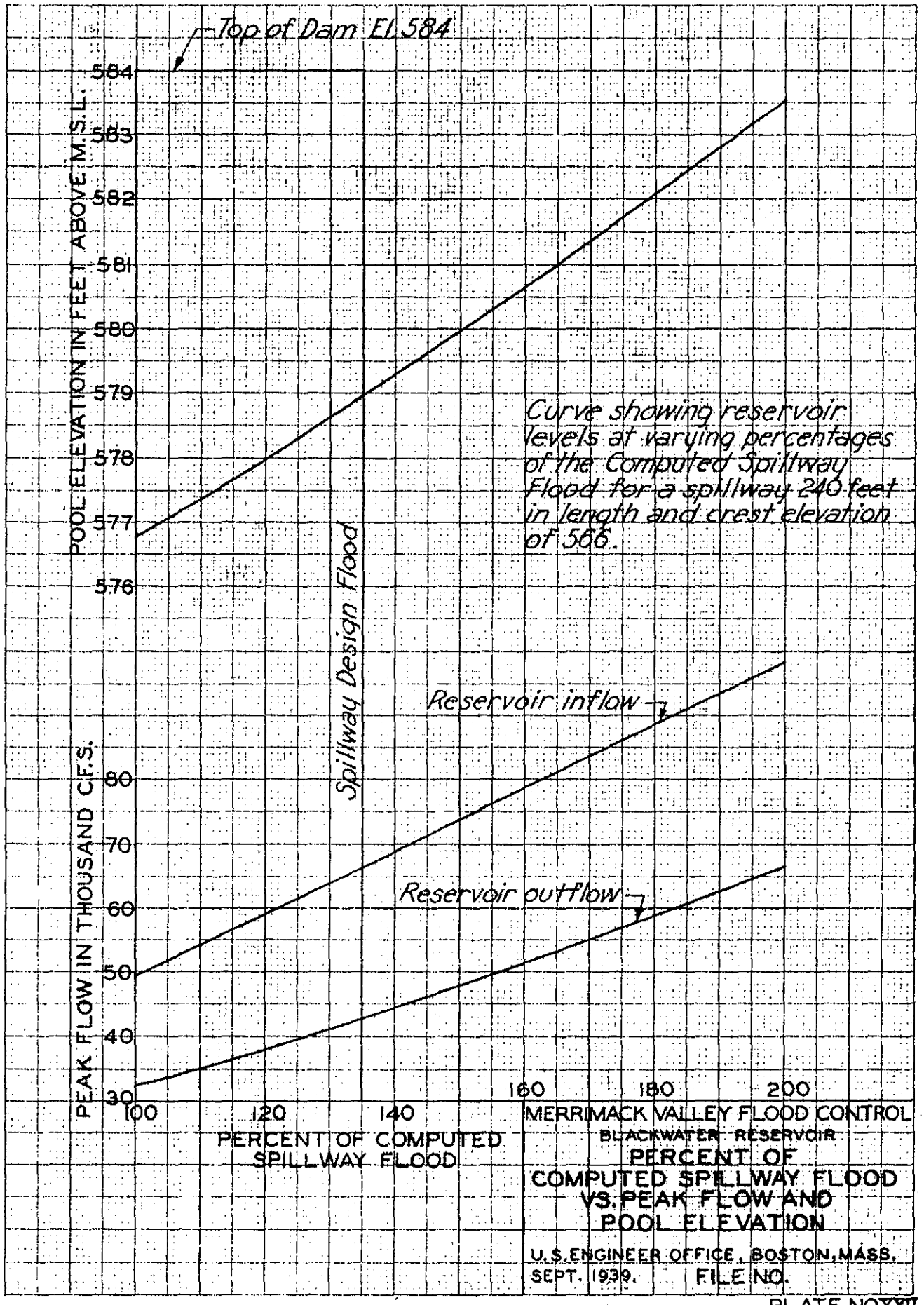
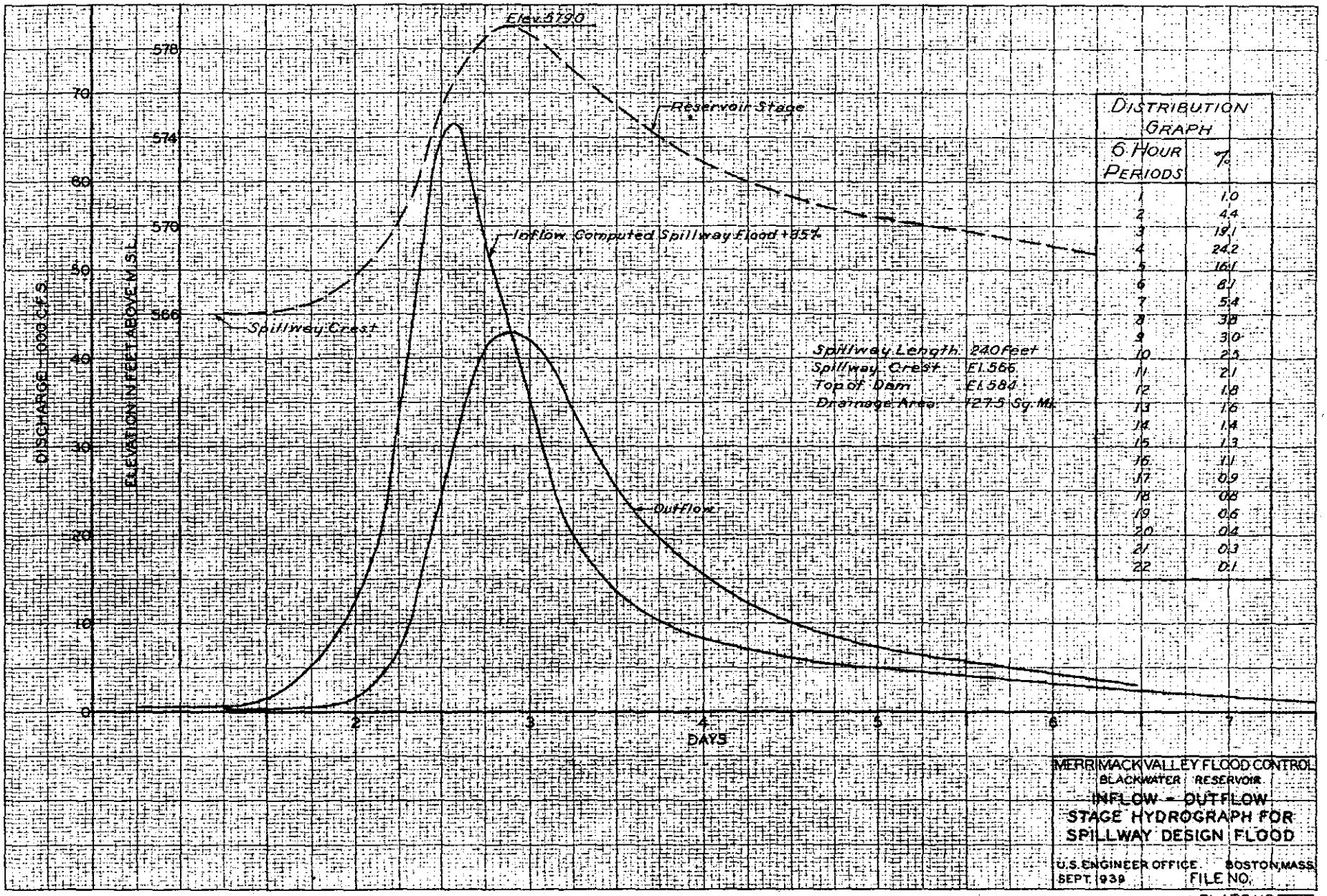


PLATE NO. XXII

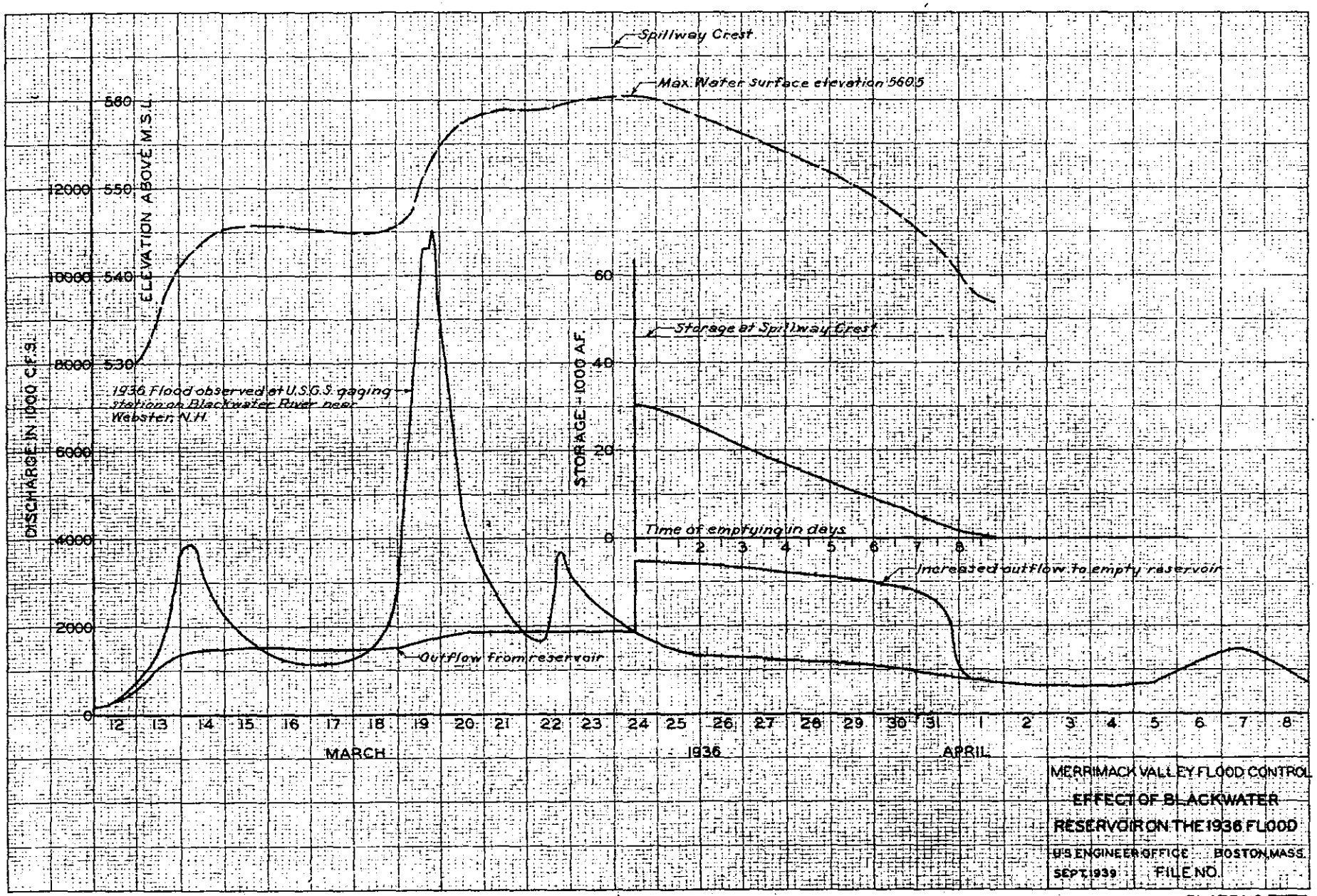


DISTRIBUTION GRAPH	
6 HOUR PERIODS	%
1	1.0
2	4.4
3	19.1
4	24.2
5	16.1
6	8.1
7	5.4
8	3.8
9	3.0
10	2.5
11	2.1
12	1.8
13	1.6
14	1.4
15	1.3
16	1.1
17	0.9
18	0.8
19	0.6
20	0.4
21	0.3
22	0.1

MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER RESERVOIR
INFLOW - OUTFLOW
STAGE HYDROGRAPH FOR
SPILLWAY DESIGN FLOOD

U.S. ENGINEER OFFICE BOSTON, MASS.
SEPT. 1939 FILE NO.

PLATE NO. XXIII



MERRIMACK VALLEY FLOOD CONTROL

EFFECT OF BLACKWATER RESERVOIR ON THE 1936 FLOOD

U.S. ENGINEER OFFICE BOSTON, MASS.

SEPT. 1939 FILE NO.

PLATE NO. XXIV

Fig 2

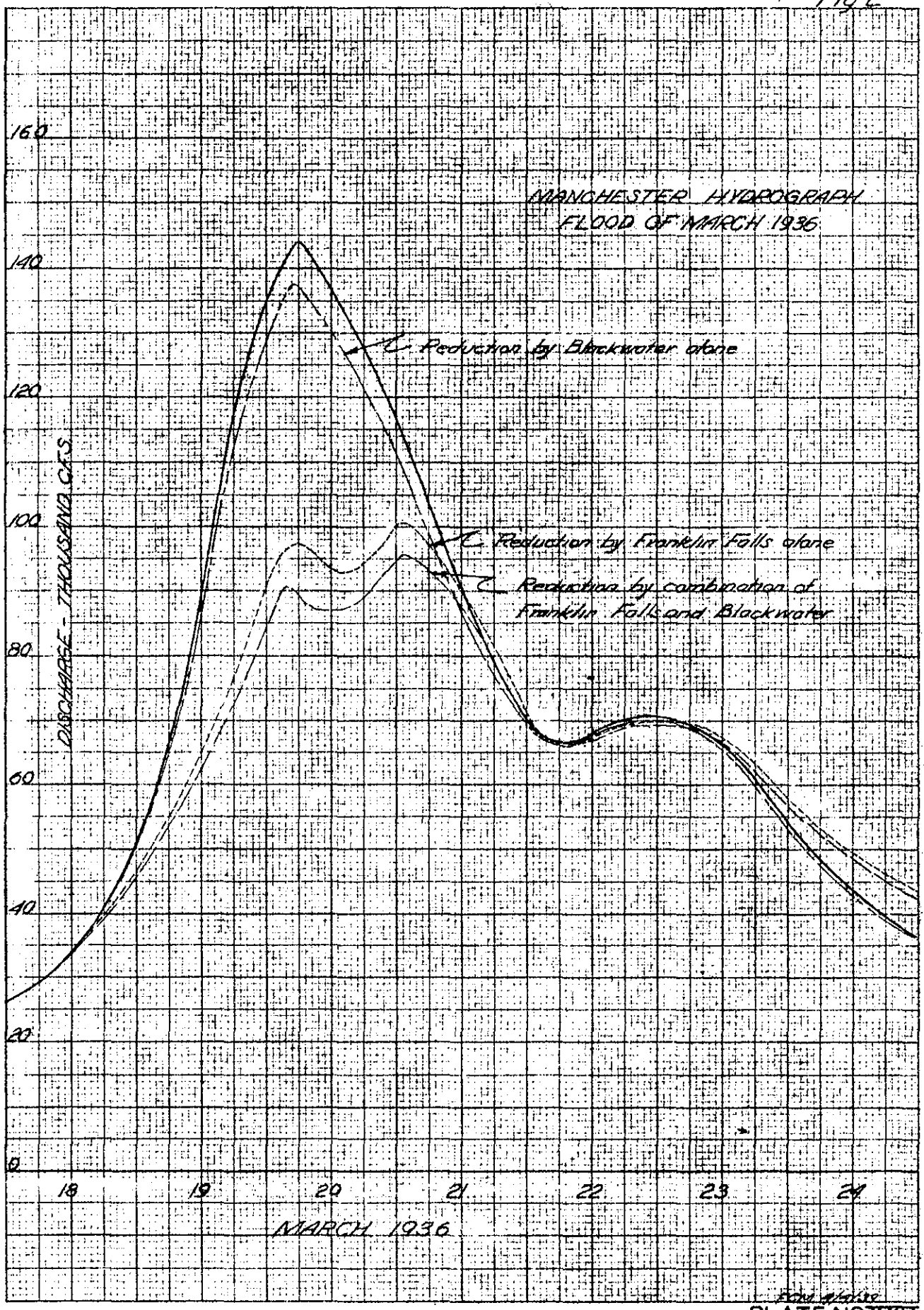


PLATE NO. XXV

KEUFFEL & ESSER CO., N. Y. NO. 359-11
20 X 20 to the inch, 10th lines heavy.
MADE IN U.S.A.

Fig 3

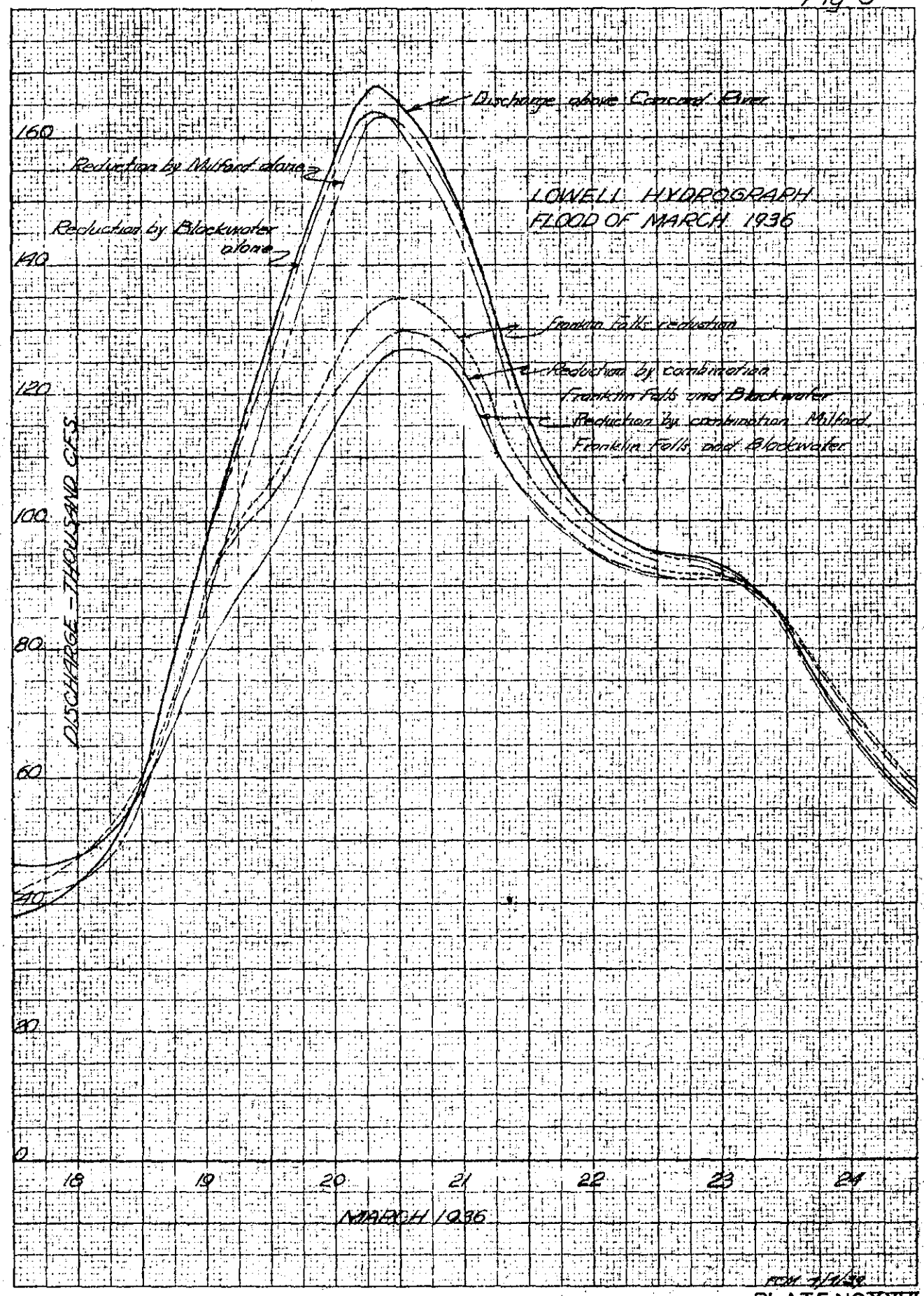


PLATE NO XXVI

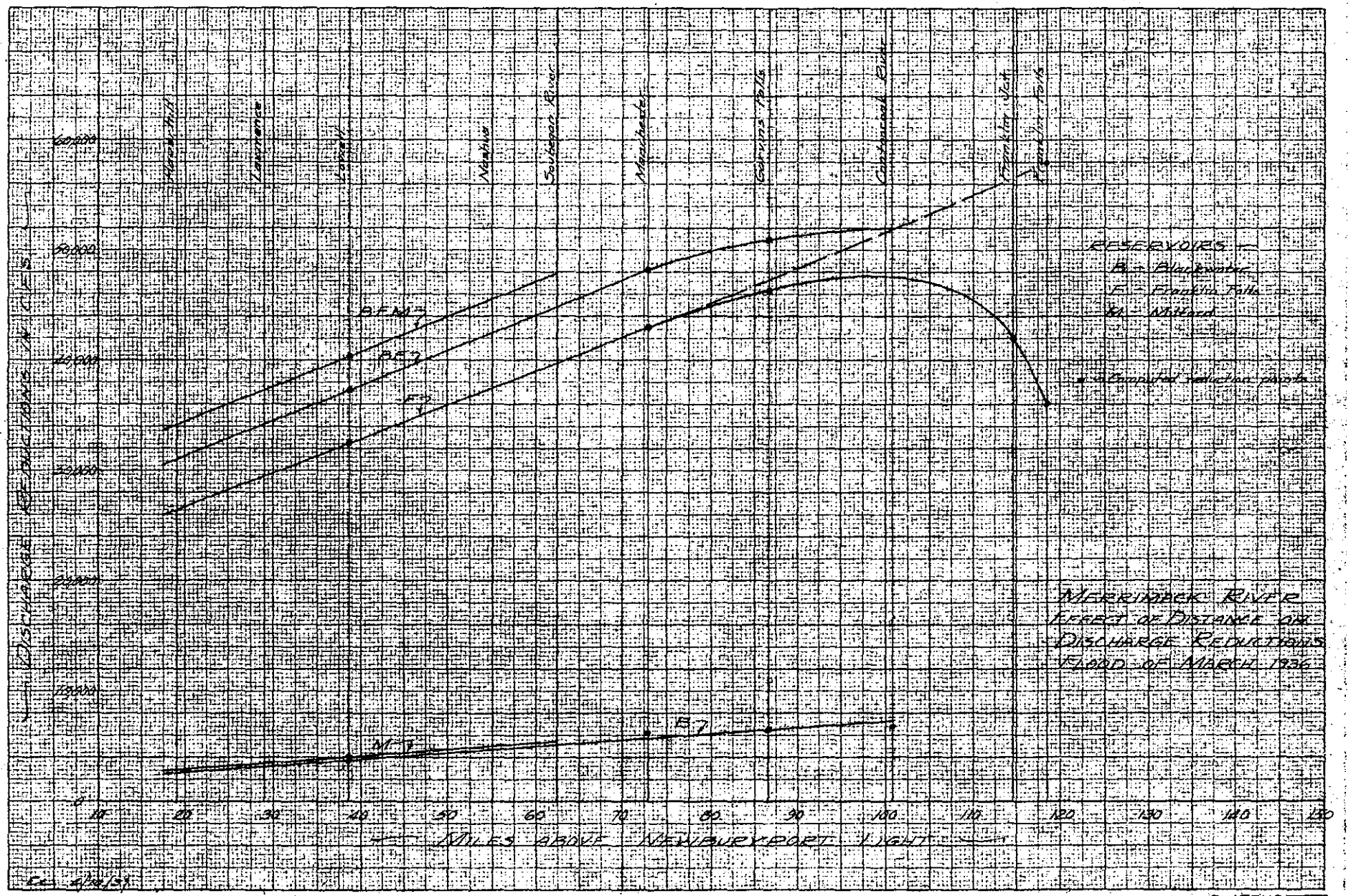
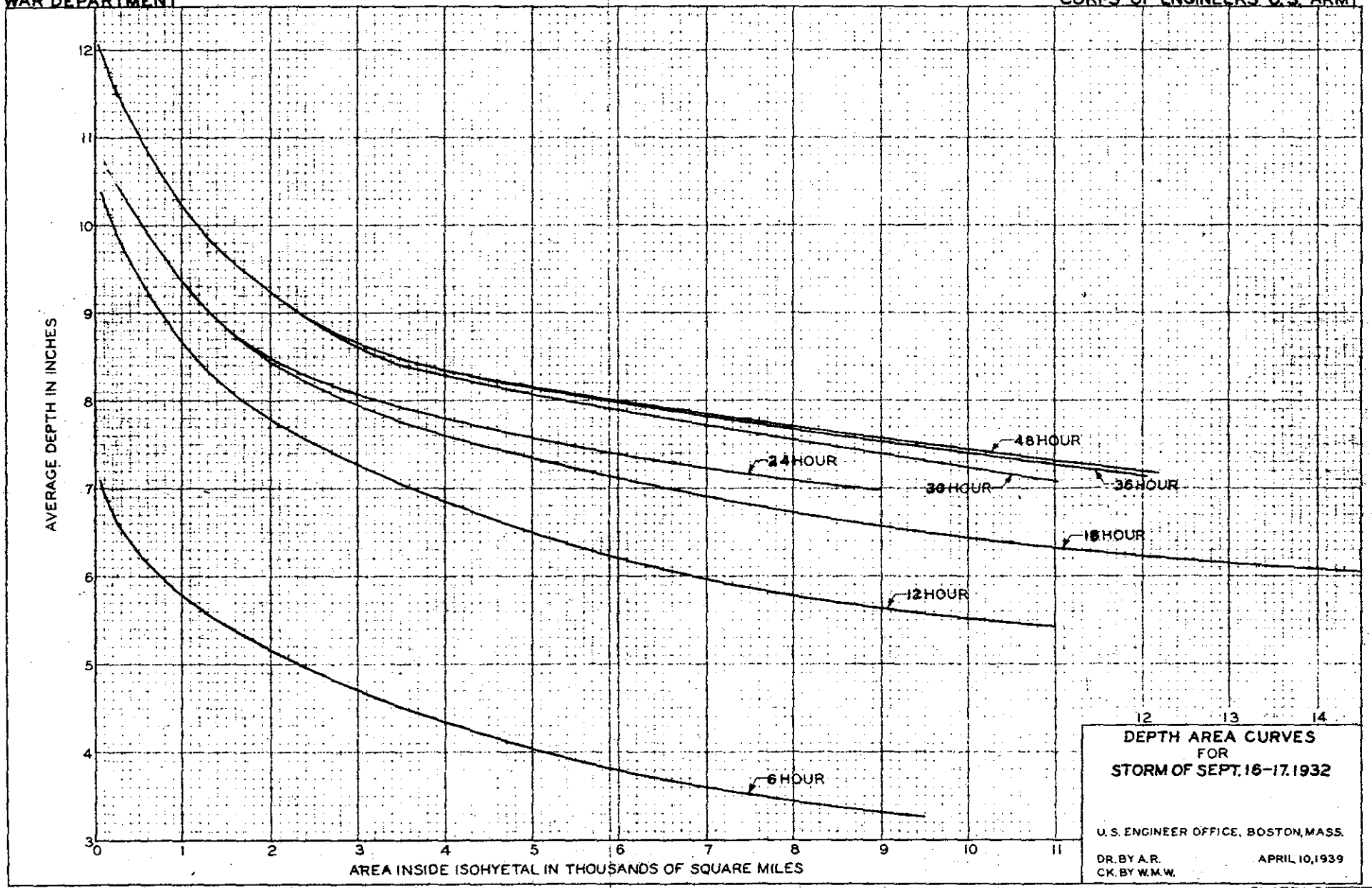


PLATE NO. XXVII

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



DEPTH AREA CURVES
FOR
STORM OF SEPT. 16-17, 1932

U.S. ENGINEER OFFICE, BOSTON, MASS.

DR. BY A.R.
CK. BY W.M.W.

APRIL 10, 1939

PLATE NO. XXVIII

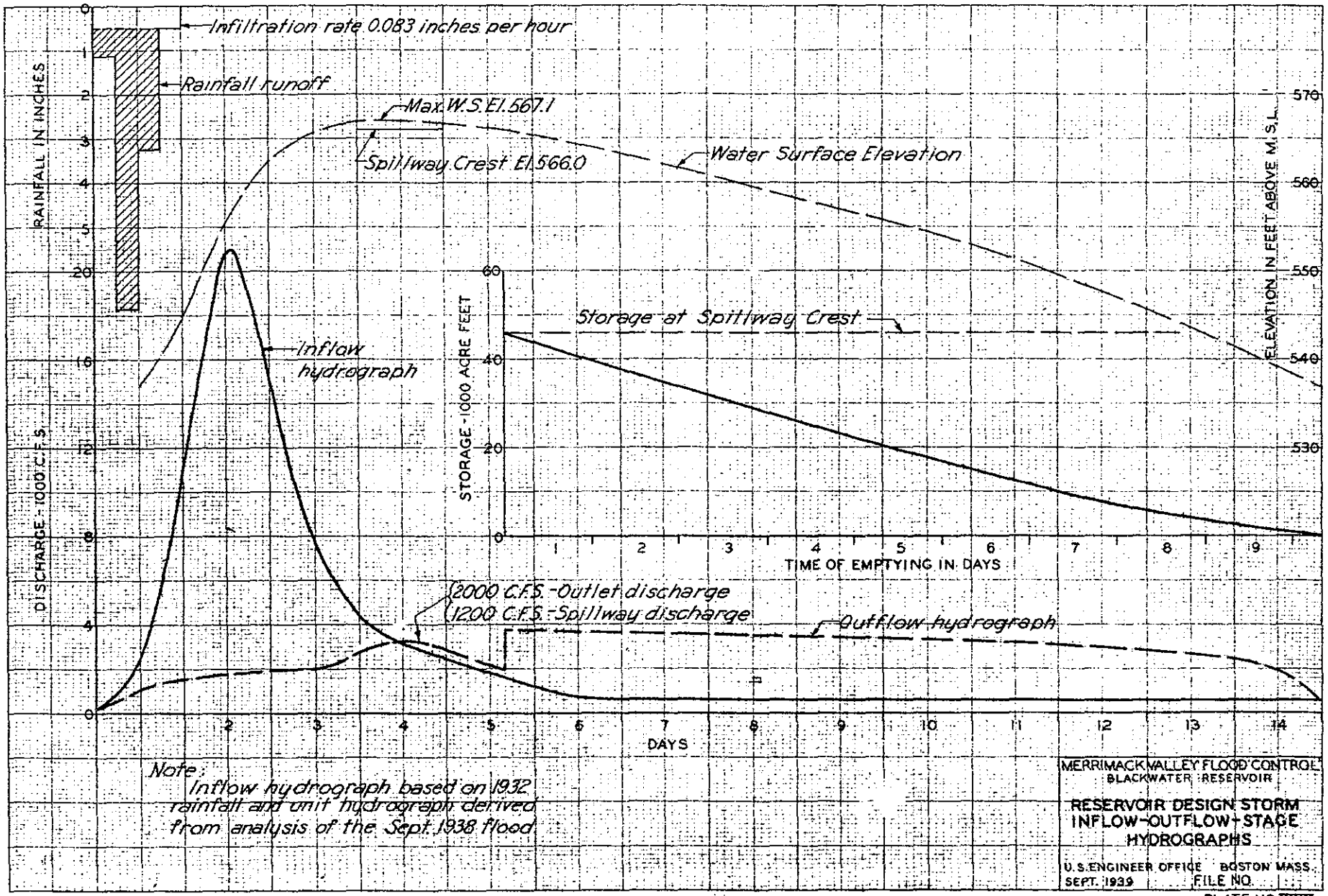


PLATE NO. XXIX

SUMMARY OF DATA FOR PROPOSED BLACKWATER RESERVOIR

Location: On the Blackwater River, 8.2 miles above the confluence with the Contoocook River and 118.8 miles above the mouth of the Merrimack River, of which the Contoocook is a tributary. The dam is just above the village of Swetts Mills, N.H., and the reservoir area is within the towns of Webster and Salisbury, Merrimack County, N.H.

Drainage Area: 127.5 square miles.

Flood Control Capacity: 46,000 acre-feet, equivalent to 6.8 inches of run-off.

General Description: The proposed initial development is for flood control only, but is adaptable to alteration for possible future use as a multiple-purpose reservoir. The reservoir area below initial spillway crest (El. 566) is 3,140 acres. The dam will have a concrete spillway, a concrete non-overflow section, and an earth fill retaining section. The initial concrete spillway is a wide-base, gravity-type Ogee section, 240 feet long at the crest, with a maximum height of 59 feet. The concrete non-overflow section consists of a 40-foot buttressed section adaptable for future intake works, and a 132-foot wide-base gravity section connecting with the earth embankment. The embankment is a semi-wide base structure of rolled earth fill and central impervious core, 690 feet long, with a maximum height of 60 feet. In addition to the main dam, two dikes, one 420 feet long with a maximum height of 20 feet, and one 1230 feet long with a maximum height of 28 feet, are required initially. The flood control outlet works consist of one 3'-6" x 6'-5" ungated outlet and three 3'-6" x 5'-3" gated outlets.

Estimated Cost:

For land, rights-of-way, and relocation	-	$ 491,000
For construction	-	818,000
Total, initial development	-	$ 1,309,000

CORRESPONDENCE

BOSTON DISTRICT

U.S. ENGINEER OFFICE
BOSTON, MASS.
SEP 25 1939

Merrimack River 7/31-a

Subject: Submission of Definite Project Report for Blackwater Reservoir - Merrimack River Basin Flood Control.

1st Ind.

Office, Division Engineer, NORTH ATLANTIC DIVISION, New York City, September 23, 1939 - To the Chief of Engineers, U. S. Army.

1. This definite project covers the Blackwater Reservoir as an element in the comprehensive plan for flood control in the Merrimack River Basin. The Blackwater Reservoir was included in alternate reservoir systems described in the survey report on the Merrimack River, published as House Document Number 689, Seventy-fifth Congress, Third Session. The plan presented by this Document was approved by Congress in Section 4 of the Flood Control Act of 1938.

2. Under the project approved by Congress, the Chief of Engineers approved the construction of the Franklin Falls Reservoir on the Pemigewasset River and the initiation of preparation of plans for Riverhill Reservoir on the Contoocook River. These two reservoirs would control substantially the floods of the Pemigewasset and Contoocook. The control of these streams is essential to, and provides the major part of justifiable flood control in the Merrimack River Basin.

3. The Franklin Falls Reservoir is under construction. Local objections to the construction of Riverhill are very strong. The State of New Hampshire has not given its consent to the purchase of the necessary lands. The Secretary of War and the Chief of Engineers have prohibited any work on Riverhill. The Federal Power Commission has proposed an alternate plan involving a number of dams in lieu of Riverhill.

4. Under these conditions the District Engineer has made further studies and has developed alternate plans for the control of the Contoocook. He finds that all practicable combinations include Blackwater, and that the most practicable plan consists of Blackwater and the Contoocook River Flood Diversion Project which is described in a preliminary definite project being forwarded. This combination is practically the equivalent of Riverhill, with costs and benefits only slightly less, and economic justifications practically the same.

5. The plan proposed for Blackwater provides for the installation of penstocks and increasing the height of the dam in the future for storage for power in addition to flood control. This plan has been discussed and an informal agreement reached with the Federal Power Commission with respect to the ultimate capacity of the multiple purpose reservoir and the size of penstock opening to be provided in the initial structure. Drawings accompanying this definite project have been prepared on this basis.

6. The estimated cost of Blackwater Reservoir including provision for future enlargement and storage for power is $1,275,000. The average annual benefits from Blackwater alone would be about three times the annual costs. The combination of Blackwater and the proposed Contoocook Flood Diversion with Franklin Falls will eliminate approximately 75% of the total average annual losses in the Merrimack River Basin. The average annual benefits from the system would exceed the annual costs.

7. It is desired to advertise this project early in the Spring of 1940. Funds sufficient to commence construction under continuing contract during the current Fiscal Year are available from the allotment to Riverhill. Since the detailed field investigations and the design of the project cannot be commenced prior to the approval of this definite project, it is requested that action be expedited.

8. It is recommended that this definite project for the Blackwater Reservoir be approved and that the District Engineer be authorized to prepare plans and specifications for approval.

F. B. WILBY
Colonel, Corps of Engineers
Division Engineer

Incls. accpg.-
7/31-a in dupl.

7402(Merrimack R.-Blackwater Res.)-8 Subject: Submission of Definite Project Report for Blackwater Reservoir-Merrimack River Basin Flood Control.

U.S. ENGINEER OFFICE

2d Ind. 3-B

GAW:ABJ:MCP:MR:mrz

Office, C. of E., October 13, 1939 - To the Division Engineer, North Atlantic Division, New York, N. Y.

1. The Definite Project Report for Blackwater Reservoir is approved subject to further study in connection with the "Spillway Design Flood" by this office.

2. It is suggested that the District Engineer arrange a conference for the discussion of certain features of the proposed design prior to the initiation of work on the preparation of construction plans and specifications, with representatives of the Division and this office present.

3. The principal features for discussion are:

a. Initial Crest Width of Earth Dam. It is believed that the embankment should be constructed with downstream slopes as proposed, a 30-foot crown and 1 on 3 upstream slope protected with 3 feet of dumped riprap. This change will reduce the initial cost and will not interfere with the ultimate enlargement, as any remaining voids in the riprap can be filled by sluicing as the upstream pervious section is being raised.

b. Concrete Cut-off Wall. The proposed concrete cut-off wall connecting the earth core and the concrete non-overflow section is objectionable as stresses in the embankment may rupture the wall and allow piping. It appears that a satisfactory solution can be obtained by offsetting the centerline of the concrete non-overflow section 6 feet, 6 inches downstream from the centerline of the earth embankment, extension of the core along the upstream face of the non-overflow section, and the provision of three keys.

c. Reinforced Concrete Buttress Section. It is believed that a considerable saving in cost can be made by the elimination of the proposed reinforced concrete buttress section containing the future flood control outlets and penstock by the extension of the gravity concrete non-overflow section to include the future penstock, the extension of the spillway on the right abutment to include the area occupied by the future flood control outlets with corresponding reduction in length on

2d Ind. (Cont'd)

the left abutment, and the placing of the two flood control outlets in the spillway section with provision for future gate operation from a gallery. This arrangement will eliminate the necessity for a costly operating house and equipment, and, with the shifting of the axis of the non-overflow section as suggested in subparagraph h, will permit the location of the spillway section in the narrow portion of the gorge with attendant savings in cost. It is also believed that the extension of the spillway into the right abutment will give better balanced flow downstream under spillway discharge conditions.

4. A print of a sketch incorporating the above ideas is inclosed.

5. Upon completion of the construction plans and specifications for the Blackwater Dam and their approval by the Department this office will consider favorably a request for funds to initiate the construction of the Blackwater project.

By direction of the Chief of Engineers:

Miles Reber,
Captain, Corps of Engineers,
Assistant Chief, River and Harbor Section.

REC'D OFFICE DIV. ENG.
NO. ATL. DIV. NEW YORK
OCT 14 1939

Inclosure:
Print - file No. RS 2/1,
in triplicate.

(Incls. 186)

U.S. ENGINEER OFFICE
BOSTON, MASS.
OCT 1 7 1939
172/176 Merrimack

Merrimack R. 7/31.1

Subject: Submission of Definite Project Report for Blackwater Reservoir - Merrimack River Basin Flood Control.

3rd Ind.

Office, Division Engineer, NORTH ATLANTIC DIVISION, New York City, October 16, 1939 - To the District Engineer, BOSTON, MASS.

To note and to initiate steps for the conference suggested in Paragraph 2 of 2d indorsement.

For the Acting Division Engineer:

C. H. CUNNINGHAM
Lieut. Colonel, Corps of Engineers

Incls. accpg.-
Merrimack R. 7/31.1-a (Incls. 186)
in dupl.

172/176 Merr. JRG/vb

4th Ind.

U. S. Engineer Office, Boston, Mass., October 28, 1939 - To the Division Engineer, North Atlantic Division, New York, N. Y.

1. Noted.

2. Conference suggested in preceding indorsements has been arranged for November 10, 1939, and is to be held in the Boston office. The Department and the Division offices were notified by telegrams dated October 26, 1939.

For the District Engineer:

D. G. White
Captain, Corps of Engineers
Executive Officer

Inc. withdrawn.

KFW:ed

ADDRESS REPLY TO
THE DISTRICT ENGINEER
U. S. ENGINEER OFFICE
5th FLOOR, PARK SQUARE BUILDING
31 ST. JAMES AVENUE
BOSTON, MASS.

REFER TO FILE No.

WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
5th FLOOR, PARK SQUARE BUILDING
31 ST. JAMES AVENUE
BOSTON, MASS.

December 22, 1939

Subject: Definite Project Report - Blackwater Reservoir.

To: The Chief of Engineers, U. S. Army, Through the Division Engineer, North Atlantic Division.

1. Reference is made to the Definite Project Report for Blackwater Reservoir submitted on September 15, 1939 (N.D. File 7402 (Merrimack R.-Blackwater Res.)-S). By 2nd Indorsement dated October 13, 1939, the Chief of Engineers approved the above definite project report subject to further study in connection with the spillway design flood. Reference is also made to a letter from the Chief of Engineers dated October 17, 1939, subject: "Spillway Design Flood, Blackwater Reservoir, Merrimack River Basin Flood Control," (N.D. File 7402(Merrimack R.-Blackwater Res.)), transmitting a memorandum outlining the scope of the further hydrological studies desired and requesting that the results of the studies be submitted to the Office, Chief of Engineers for approval.

2. One 5' x 7' ungated outlet with a capacity of 1500 sec.-ft. at a reservoir level of 566 feet (initial spillway lip elevation) was originally proposed. With this outlet the time required to empty the reservoir was about two weeks assuming zero inflow, or about one month assuming an inflow of 5 sec.-ft. per square mile. After further study as suggested, and with due consideration to the requirements of design outflow in both the initial and ultimate development, the outlet works have been changed to provide one ungated outlet and three gated outlets with a total capacity of 3760 c.f.s. at reservoir elevation 566. This change will reduce the time required to empty the reservoir to about 9 days for the initial plan and 10 days for the ultimate plan.

3. The peak inflow of the spillway design flood originally proposed was 48,000 sec.-ft., which gives a value of 4260 for the coefficient "C" in the formula $Q = C\sqrt{A}$. As suggested, the effect of a sharper peaked unit hydrograph has been considered and a new spillway design flood adopted with a peak inflow of 66,500 sec.-ft., giving a value of 5880

for the coefficient "C". The additional spillway capacity required to pass this increased peak flow could be obtained by lengthening the spillway from 155 feet to 204 feet with a resulting surcharge of 14 feet and freeboard of 5 feet as originally planned. With a spillway 240 feet long, however, the surcharge at maximum water surface is only 13 feet and the freeboard 5 feet with the dam at elevation 354, or one foot lower than originally planned. Since lowering the dam one foot was found to be more economical than limiting the length of spillway, the 240-foot length was adopted.

4. Details of the foregoing additional studies are submitted herewith in the form of revised Appendices A and B to the Definite Project Report, together with illustrations referred to in those appendices. A completely revised definite project report to take into account the changes in layout and design required as a result of these studies is not submitted for the following reasons:

a. Final plans and specifications, together with the basis and analysis of design will be completed by January 15, 1940.

b. The drafting and reproduction required for a revised definite project report would delay the progress on the final work described in a above and, in any event, could not be accomplished much before January 15, 1940.

c. The changes required will not increase the estimated costs appreciably, nor affect the general principles of layout and design which have already been approved.

5. As an interim report for the information of the Department, in lieu of a revised definite project report, a summary of data on one sheet is submitted herewith.

6. Final approval of the definite project report for Blackwater Reservoir including the revised hydrological studies and resulting changes is requested.

For the District Engineer:

D. S. White
Captain, Corps of Engineers
Executive Officer

Enclosures: (in quad.)
Revised Appendices A & B,
with illustrations
Summary of Data

cc: File
Reading File
Mr. Weber