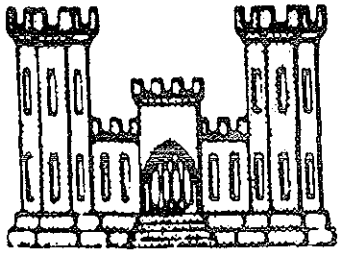
CONNECTICUT RIVER FLOOD CONTROL

COLEBROOK RIVER
DAM & RESERVOIR

WEST BRANCH, FARMINGTON RIVER
CONNECTICUT & MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

HYDRAULIC ANALYSIS



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

APRIL 1964

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASS. 02154

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDED-R

30 April 1964

SUBJECT: Colebrook River Dam and Reservoir, Farmington River, Connecticut River Basin, Massachusetts and Connecticut, Design Memorandum No. 8, Hydraulic Analysis

TO: Chief of Engineers
ATTN: ENGCW-E
Washington, D. C.

There is submitted herewith for review and approval Design Memorandum No. 8, Hydraulic Analysis for the Colebrook River Dam and Reservoir, Farmington River, Connecticut River Basin, in accordance with EM 1110-2-1150.

FOR THE DIVISION ENGINEER:

JOHN WM. LESLIE
Chief, Engineering Division

1 Incl
as (5 cys)

BIBLIOGRAPHY OF DESIGN MEMORANDA

COLEBROOK RIVER DAM AND RESERVOIR

INDEX

Design Memo No.	Title	Submission Date	Approved
1	Site Selection	13 Mar 1963	11 Apr 1963
2	Hydrology		
	Preliminary	3 Jul 1963	10 Jul 1963
	Final	12 Nov 1963	19 Dec 1963
3	Site Geology		
4	Real Estate Design Memorandum		
5	Relocations	31 Mar 1964	
6	General Design Memorandum	31 Mar 1964	
7	Concrete Materials	27 Sep 1963	18 Oct 1963
8	Hydraulic Analysis	30 Apr 1964	
9	Embankments and Foundations		
10	Detailed Design of Structures		
11	Reservoir Development (Preliminary)	30 Apr 1964	
11A	Reservoir Development (Master Plan)		

COLEBROOK RIVER DAM AND RESERVOIR

WEST BRANCH FARMINGTON RIVER
CONNECTICUT RIVER BASIN
CONNECTICUT AND MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

HYDRAULIC ANALYSIS

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8-5	Outlet Works
8-6	Outlet Rating Curves
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COLEBROOK RIVER DAM AND RESERVOIR

WEST BRANCH FARMINGTON RIVER
CONNECTICUT RIVER BASIN
CONNECTICUT AND MASSACHUSETTS

DESIGN MEMORANDUM NO. 8

HYDRAULIC ANALYSIS

1. PURPOSE

The purpose of this memorandum is to describe the hydraulic criteria applicable to the design of the Colebrook River Dam and Reservoir on the West Branch of the Farmington River, Farmington River basin. This design memorandum includes sections on the spillway, approach and discharge channels, spillway slope, flood control outlets and miscellaneous structures. The reservoir area is shown on Plate Nos. 8-1 and 8-2. A general plan of the dam is shown on Plate No. 8-3.

2. SPILLWAY

a. General. The natural topography at the dam site together with the favorable rock formation led to the selection of a chute spillway. The spillway structure will consist of an approach channel, an ogee concrete weir and a discharge channel excavated in rock. Details of the weir and approach and discharge channels are discussed in the following paragraphs and are shown on Plate No. 8-4.

b. Crest elevation. At the selected spillway crest elevation of 756 msl the reservoir will contain 30,700 acre-feet of water supply storage, and 50,800 acre-feet of flood control storage. The flood control storage capacity is equivalent to 8.0 inches of runoff from the 118 square miles of drainage area.

c. Length of crest and maximum surcharge. Assuming the pool initially at elevation 744 feet msl which represents 6 inches of flood control storage, the spillway design flood was routed through the remaining reservoir and surcharge storage assuming various lengths of weir. The flood control gates were assumed to be operative. The selected crest length of 205 feet and corresponding

maximum reservoir surcharge of 24 feet (780 feet msl) was found to be the most economical. The surcharge storage reduced the spillway design flood inflow of 165,000 cfs to an outflow of 96,000 cfs, of which 92,000 cfs is the spillway design discharge and 4,000 cfs is passed through the outlet.

d. Spillway approach. The approach channel to the spillway weir will be approximately 360 feet long. The high ground approaching the spillway will be excavated to elevation 742 providing a minimum approach depth of 14 feet. In order to reduce the head loss in the approach channel the width will vary from about 200 feet at the spillway to a maximum of about 300 feet. The bottom elevation will have a 1 percent slope for drainage. Computations show that the maximum velocity in the approach channel will be about 12 fps resulting in a friction loss of 0.3 foot. The plan and profiles of the approach channel are shown on Plate No. 8-4.

e. Discharge coefficient. In order to effect maximum economy and to improve the discharge efficiency, the spillway weir was designed for a head of 18 feet on the crest which is 75 percent of the maximum surcharge. For stability reasons a 3 on 2 sloping upstream face was selected for the spillway. Discharge coefficients for vertical and sloping upstream faces are shown on Plate No. 7 of the Manual for Hydraulic Design of Spillways. Plate No. 6 of the same Manual gives recommended discharge coefficients for ogee crests with vertical upstream faces. The data presented on these two plates were correlated to determine the discharge coefficients for the adopted spillway shape. The discharge coefficient versus head is shown on Plate No. 8-4.

f. Spillway rating curve. The discharge rating curve shown on Plate No. 8-5 was computed by using discharge coefficients described in the previous paragraph in the conventional weir formula making allowance for friction losses in the approach channel. A maximum friction loss in the approach channel of 0.3 foot was computed for the design discharge of 92,000 cfs.

g. Crest shape. The shape of the ogee crest was determined from Hydraulic Design Charts 111-8 in the data book of Hydraulic Design Criteria. A design head of 18 feet was used in the formula $Y = 0.0497\ X^{1.81}$ to determine the shape of the weir below the crest. An apron curve with a radius of 20 feet is provided at the toe of the weir. A typical section of the spillway weir is shown on Plate No. 8-4.

3. SPILLWAY CHUTE

a. General. The spillway chute shown on Plate No. 8-4 will satisfy hydraulic criteria as well as rock requirements for the dam. The selected channel is the result of a number of trials involving variations of cross section and invert slope. The analyses were made for the spillway design discharge of 92,000 cfs. Hydraulic computations were made to determine velocities and water surface elevations starting from the spillway apron.

b. Design of chute. The selected chute bottom width converges from 199 feet along the toe of the weir (Station 20+29) to a minimum of 100 feet at Station 25+45. The slope of the chute invert varies from 6.0 to 24.0 percent to satisfy the slope of the rock topography and to insure supercritical flow between the apron and tailwater control. During the spillway design flood, the tailwater will be at elevation 650 feet msl which is the maximum surcharge level of the West Branch Reservoir for the spillway design discharge.

c. Water surface profile. The water surface profile, as shown on Plate 8-4, for the design discharge of 92,000 cfs was computed from drop-down computations using an "n" value of 0.035 for the roughness coefficient. The starting elevation at the toe of the spillway was determined by the specific energy equation assuming that friction and other losses at the weir were equal to 10 percent of the total available energy head on the spillway crest. Convergence losses, due to impact and turbulence, were assumed to be 20 percent of the difference in velocity heads at the sections. The velocity accelerates from about 35 fps at the spillway apron to about 40 fps at Station 24+00 and to about 70 fps at Station 27+50. A minimum freeboard of 5 feet is maintained along the right bank of the discharge channel from the weir to Station 24+00.

4. FLOOD CONTROL OUTLET

a. General. Design criteria for the outlet works at Colebrook River Dam are described in Design Memorandum No. 1, Hydrology, pages 18 and 19. In general, the outlet works must satisfy the water supply demands of the Metropolitan District Commission and also be adequate to pass a flow equal to the safe downstream channel capacity without utilizing appreciable storage in Colebrook River Reservoir.

b. Outlet and gates. A circular tunnel with a diameter of 10 feet and an area of 78.54 square feet satisfies the discharge

requirements. The outlet will have a discharge capacity of about 3,400 cfs with the reservoir level at the top of the water supply pool and 5,800 cfs with the reservoir filled to spillway crest. The total cross sectional area of the three 4' x 8' sluice gates is 96 square feet. These gate sizes make it possible to discharge 95 percent of the total capacity should one gate become inoperative with the pool at spillway crest.

c. Invert elevations. From the intake to the end of the transition at Station 7+60.91 the invert will be level at elevation 575 feet msl. From this point the tunnel invert will slope 0.31 percent to elevation 573.0 at the portal at Station 14+00.

d. Intake. The vertical curve at the intake roof, as shown on Plate No. 8-7, for each of the three gate passages is based on the formula:

$$\frac{X^2}{1.5D^2} + \frac{Y^2}{\left(\frac{1.5D}{3}\right)^2} = 1,$$ where D = 8'-0", the vertical

dimension of each passageway. Side curves at the intake, as shown on Plate No. 8-8, were determined from the following equation:

$$\frac{X^2}{56.25} + \frac{Y^2}{6.25} = 1,$$ where the X axis is located along the

center line of the piers and the Y axis is located 3.5 feet upstream of the stop-log slot.

e. Trash structure. A trash rack will be provided for the intake in accordance with Engineering Manual for Civil Works construction EM 1110-2-2400, Chapter 3, paragraph 3-05. The average velocity through the clear area of the trash structure will vary from about 4 to 8 fps. The maximum velocity occurs with a discharge of 5,800 cfs and the pool at elevation 756 feet msl.

f. Outlet transition. Details of the proposed transition conforming generally to criteria described in EM 1110-2-1602, paragraph 23, are shown on Plate No. 8-9. The areas of the gate passageway are maintained constant to the end of the piers. The total width of the intake converges in a distance of about 100 feet from 22 feet to a conduit width of 10 feet. The rate of convergence is 1 foot in 17 feet, which is about equivalent to using a convergence rate based on 10 percent of the operating head. From the end of the piers of the

gate passageways to the end of the transition the roof rises from elevation 583 to 585 while the bottom remains level at elevation 575.

g. Air vent. Computations following procedures described in the Engineering Manual for Civil Works Construction, Hydraulic Design of Reservoir Outlet Structures dated 1 August 1963, indicate that with the pool at elevation 780 feet msl (maximum surcharge), the maximum air demand per gate would be about 630 cfs. Assuming a maximum velocity of 150 fps, the air vent will require a cross sectional area of 4.2 square feet per gate. Vents 4'-0" by 1'-3" are provided to enter the gate passage immediately downstream from the gate and are shaped to prevent cavitation tendencies. These vents join into three 30-inch risers located within the gate control structure with an entrance located in the freeboard range above the maximum surcharge elevation. With the air vent designed for a maximum velocity of 150 fps, the computed pressure drop or head loss in the vents will equal 1.1 feet of water.

h. Tunnel characteristics. Hydraulic elements of the 10-foot diameter concrete lined tunnel are shown on Plate No. 8-5. The illustrated characteristics include half section, area, hydraulic radius, and discharges at both normal and critical depths. The velocity and discharge for normal conditions were based on Manning's formula with an "n" value of 0.013 and an invert slope of 0.31 percent.

i. Outlet rating curves. Outlet rating curves for one, two and three gates fully open with no effect of tailwater are shown on Plate No. 8-5. The hydraulic control with one gate fully open was found to be in the gate passageway for all flows. It is also in the gate passageway for two gates fully opened up to a pool elevation of approximately 582. When the pool is above this elevation for two and three gates fully open, computations indicate that the control shifts to the conduit portal.

Rating curves for the outlet are dependent upon the pool elevation of West Branch Reservoir. Plate No. 8-6 shows the rating curve of the Colebrook River conduit with the pool of West Branch Reservoir as a parameter.

The outlet at Goodwin Dam was designed to pass the flow required to meet riparian commitments. When inflow exceeds the regulated outflow, it is stored in the West Branch Reservoir. If the reservoir is filled excess flow discharges over the spillway which is at

elevation 641. With the West Branch pool at spillway crest, the Goodwin Dam outlet capacity is about 1,600 cfs. This limited outlet capacity will cause the West Branch pool to rise when the flow from Colebrook River dam exceeds 1,600 cfs, thus affecting the discharge capacity of the Colebrook outlet as indicated on Plate No. 8-6.

Following a flood regulation period water will be evacuated from Colebrook Reservoir at a rate of 3,400 cfs, the estimated downstream safe channel capacity. As this rate exceeds the outlet capacity at Goodwin Dam the West Branch Reservoir will fill to elevation 642 with about 1,800 cfs discharging over the spillway. The minimum water surface in Colebrook River Reservoir during this condition would be elevation 700.

j. Analysis of flow conditions. Pressure and energy gradient profiles for two conditions of flow, namely, maximum capacity of the conduit with all gates fully open with no tailwater, and with West Branch Reservoir at elevation 650 are shown on Plate No. 8-5. With both Colebrook River and West Branch Reservoirs at maximum surcharge and all gates at Colebrook fully open the outlet will discharge 4,960 cfs. With similar conditions at Colebrook River Reservoir, but with no tailwater the outlet will discharge 6,180 cfs. For structural design the greatest pressure in the tunnel downstream of the gates will exist with the pressure gradient at elevation 705 and a discharge of 6,180 cfs. Upstream of the gates the greatest pressure will occur when all the gates are closed and the water surface is at the maximum surcharge elevation 780 feet msl.

k. Outlet channel. There are no provisions for a conventional stilling basin since the discharge channel is located in deep rock. Furthermore the outlet will be submerged a great part of the time obviating the formation of a hydraulic jump. Instead, a concrete apron flared to a width of 26 feet in a distance of 40 feet will be provided (see Plate No. 8-5). The apron will be paved and will drop from elevation 573 at the conduit portal to elevation 572. A 1-foot rise at the end of the apron will serve as a deflector to spread the flow and reduce scour at the end of the concrete. The bottom of the discharge channel will begin at elevation 572 feet msl and will maintain a slope of 0.02 and a bottom width of 26 feet throughout its length. The channel in the rock section is approximately 250 feet long and will consist of a trapezoidal channel with four vertical on one horizontal side slopes. The discharge channel in earth will have one vertical on two horizontal side slopes and will continue about 250 feet until it joins the West Branch Farmington River.

The normally high tailwater condition created by the pool of the West Branch Reservoir will tend to minimize erosive conditions in the earth section of the outlet channel.

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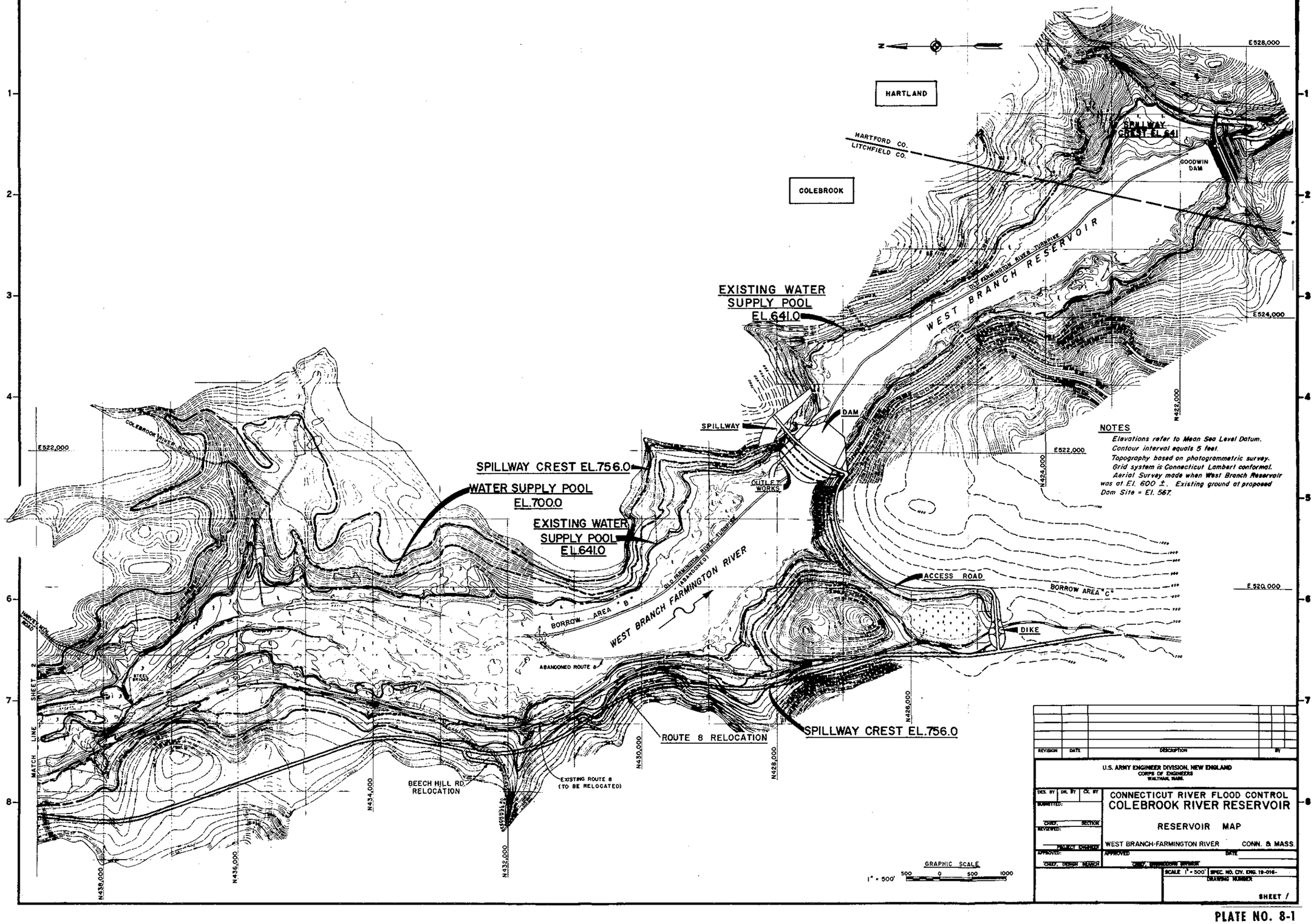

NOTES

Elevations refer to Mean Sea Level Datum.
Contour interval equals 5 feet.
Topography based on photogrammetric survey.
Grid system is Connecticut Lambert conformal.
Aerial Survey made when West Branch Reservoir was at El. 600 ±. Existing ground at proposed Dam Site = El. 567.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, SECTION

REVIEWED: PROJECT ENGINEER

APPROVED: CHIEF, DESIGN BRANCH

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER RESERVOIR
RESERVOIR MAP

WEST BRANCH-FARMINGTON RIVER CONN. & MASS.

APPROVED DATE

CHIEF, ENGINEERING DIVISION

SCALE 1" = 500' | SPEC. NO. CIV. ENG. 19-016-

DRAWING NUMBER

SHEET /

PLATE NO. 8-1

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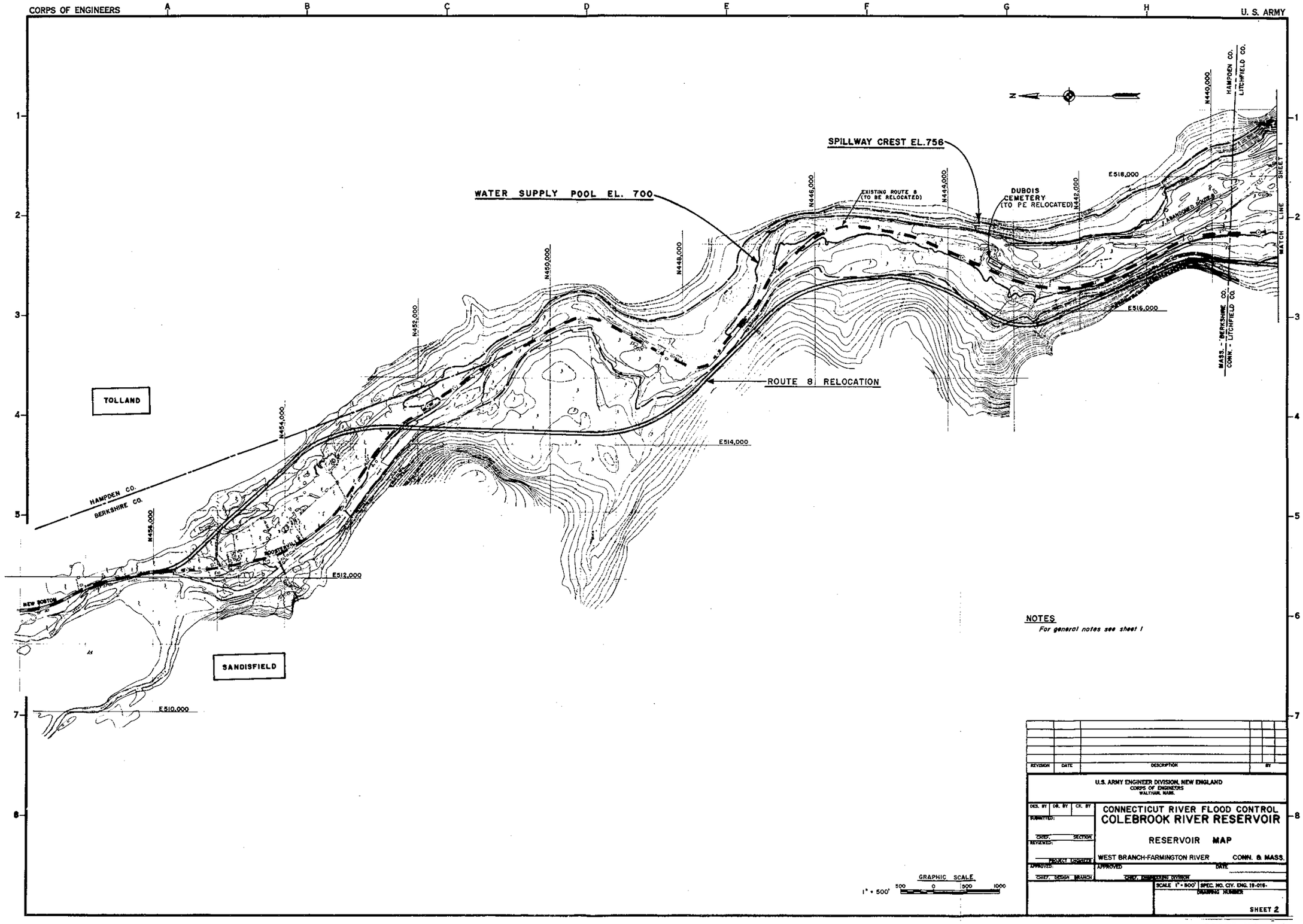

NOTES

For general notes see sheet 1

GRAPHIC SCALE

1" = 500' 500 0 500 1000

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APPROVED: CHIEF, DESIGN BRANCH

APPROVED: CHIEF, ENGINEERING DIVISION DATE

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER RESERVOIR

RESERVOIR MAP

WEST BRANCH-FARMINGTON RIVER CONN. & MASS.

SCALE 1" = 500' | SPEC. NO. CIV. ENG. 19-016-
DRAWING NUMBER

SHEET 2

PLATE NO. 8-2

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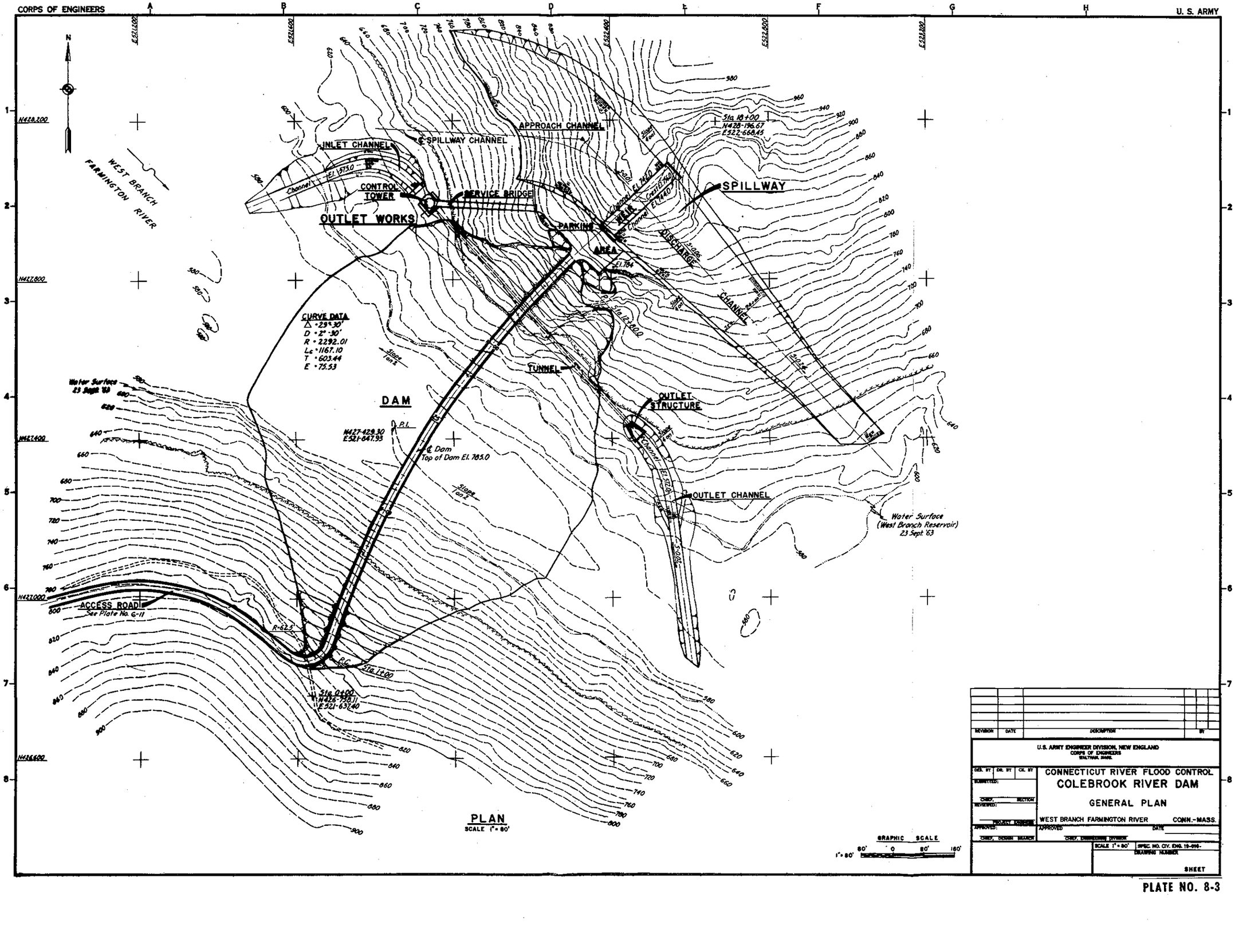

PLAN
SCALE 1" = 80'

GRAPHIC SCALE
1" = 80'
80' 0 80' 160'

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CHIEF, SECTION

REVIEWED:
PROJECT ENGINEER

APPROVED:
CHIEF, DESIGN BRANCH

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER DAM
GENERAL PLAN

WEST BRANCH FARMINGTON RIVER CONN.-MASS.

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE 1" = 80' | SPEC. NO. CIV. ENG. 16-998-
DRAWING NUMBER
SHEET

PLATE NO. 8-3

CORPS OF ENGINEERS

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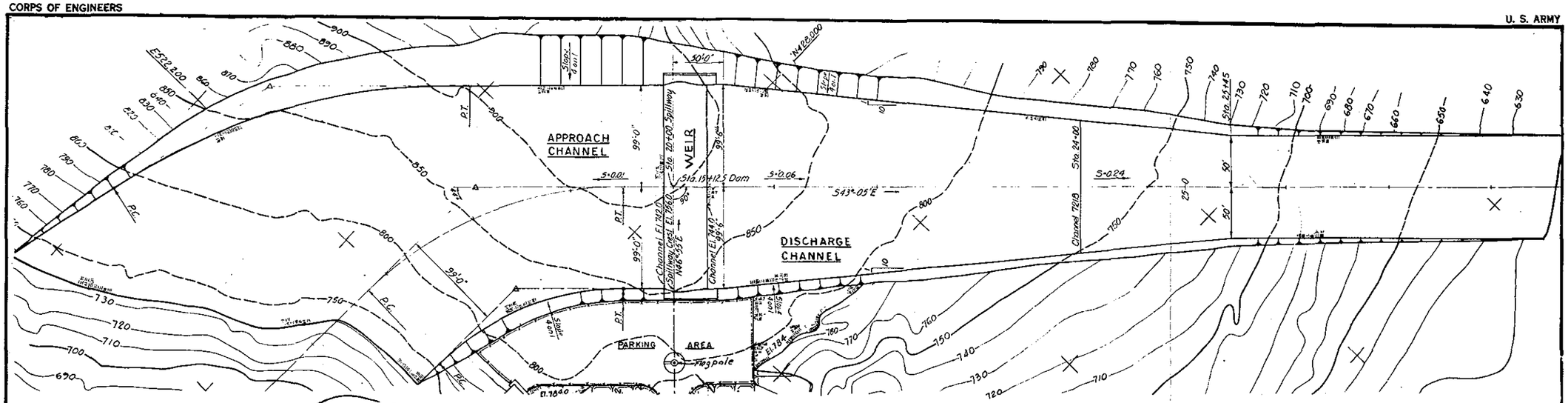

SPILLWAY PLAN

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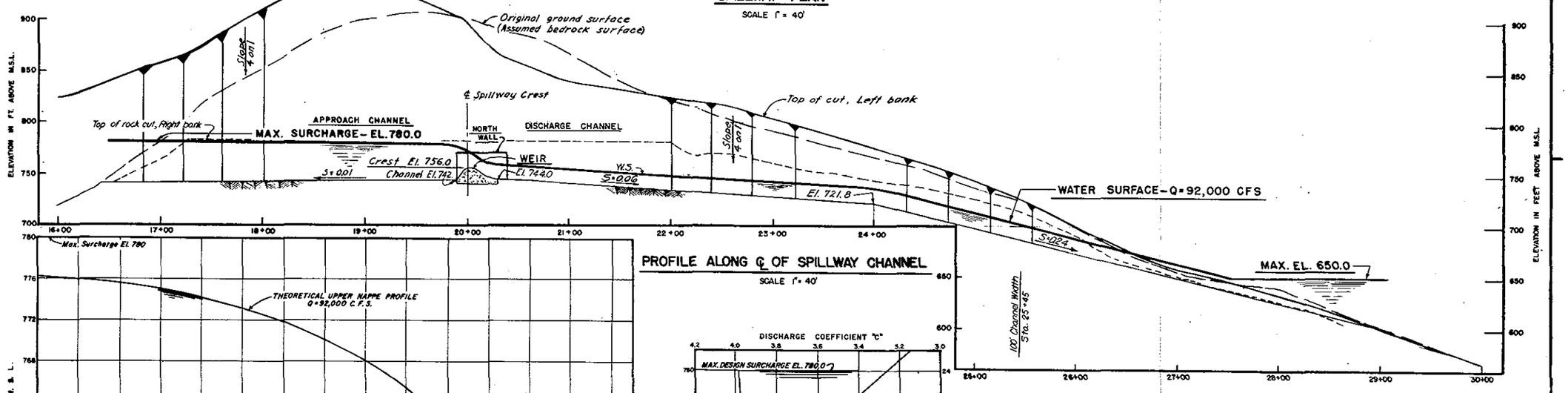
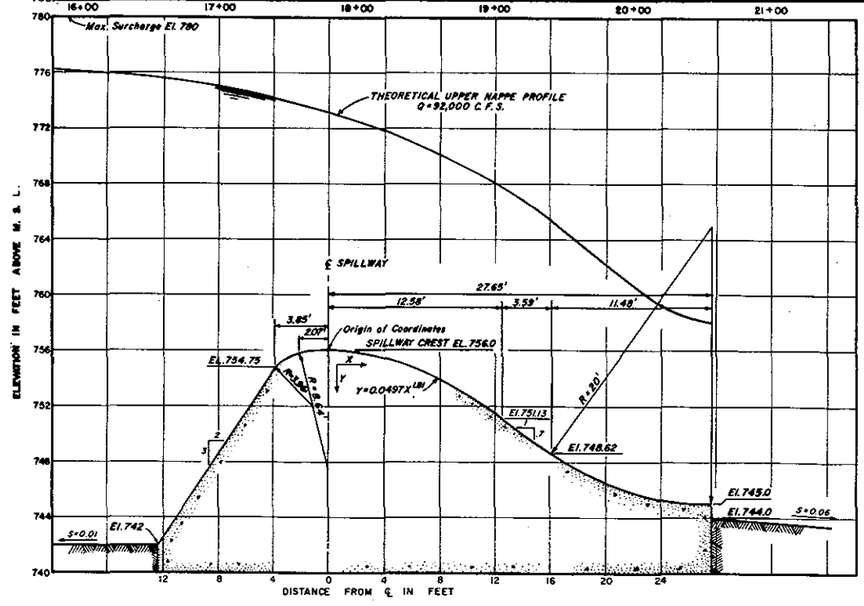
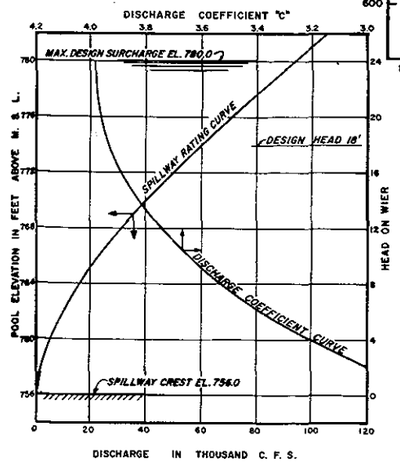


PROFILE ALONG ℄ OF SPILLWAY CHANNEL

SCALE 1" = 40'



SPILLWAY SHAPE



SPILLWAY RATING CURVE

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SUBMITTED: CHIEF, SECTION

REVIEWED: PROJECT ENGINEER

APPROVED: CHIEF, DESIGN BRANCH

APPROVED DATE CHIEF, ENGINEERING DIVISION

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER RESERVOIR
SPILLWAY AND DISCHARGE CHANNEL
PLAN AND PROFILE
WEST BRANCH-FARMINGTON RIVER CONN.-MASS.

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SHEET

PLATE NO. 8-4

CORPS OF ENGINEERS

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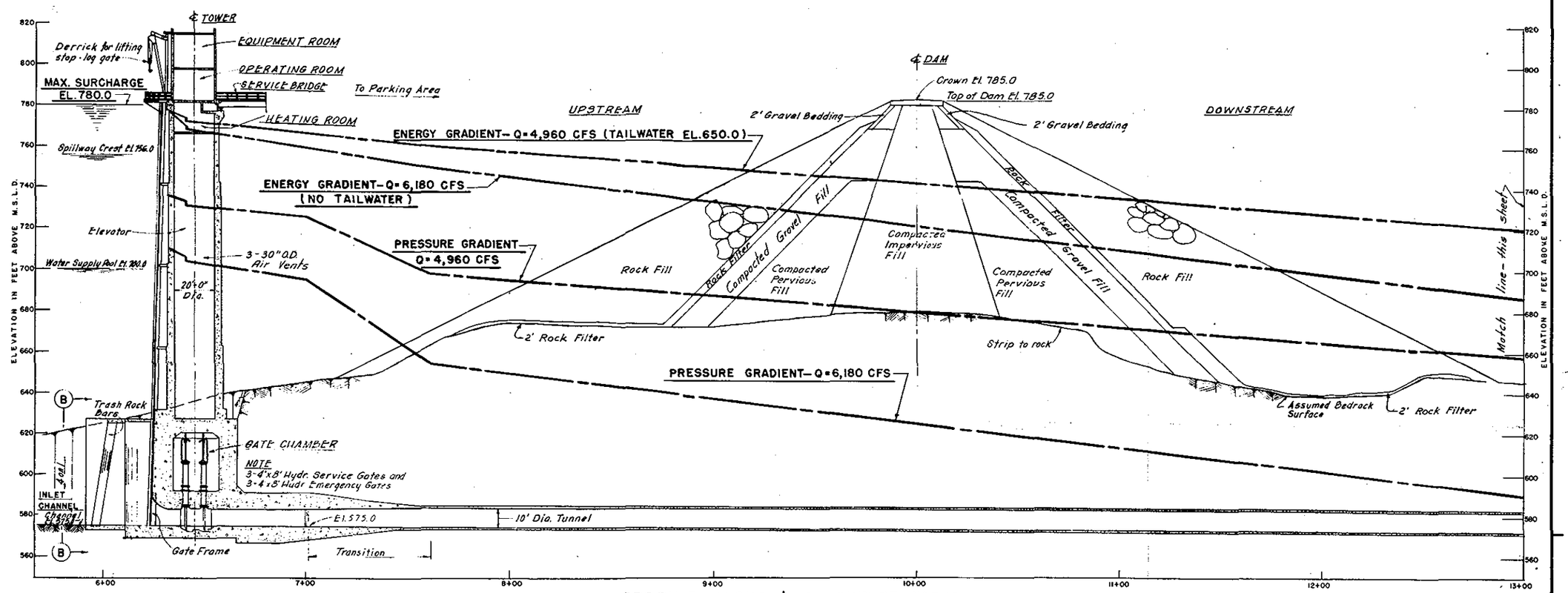
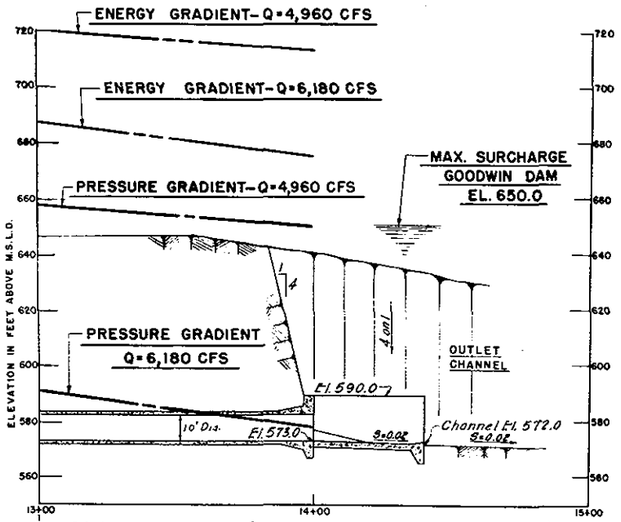


PROFILE ALONG ℄ OF OUTLET WORKS

SCALE: HOR. 1"=20'
VER. 1"=20'



PROFILE ALONG ℄ OF OUTLET WORKS (CONT'D)

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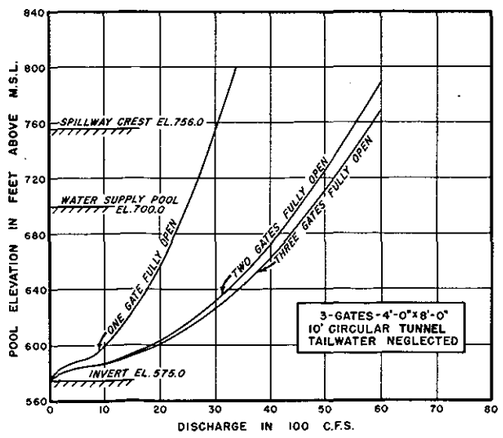
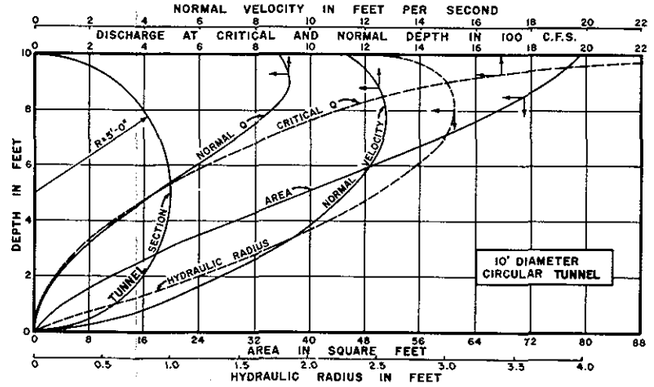


OUTLET RATING CURVES



HYDRAULIC ELEMENT CURVES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
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APPROVED:
CHIEF, DESIGN BRANCH

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER DAM
OUTLET WORKS

W. BR. FARMINGTON RIVER — CONN - MASS.

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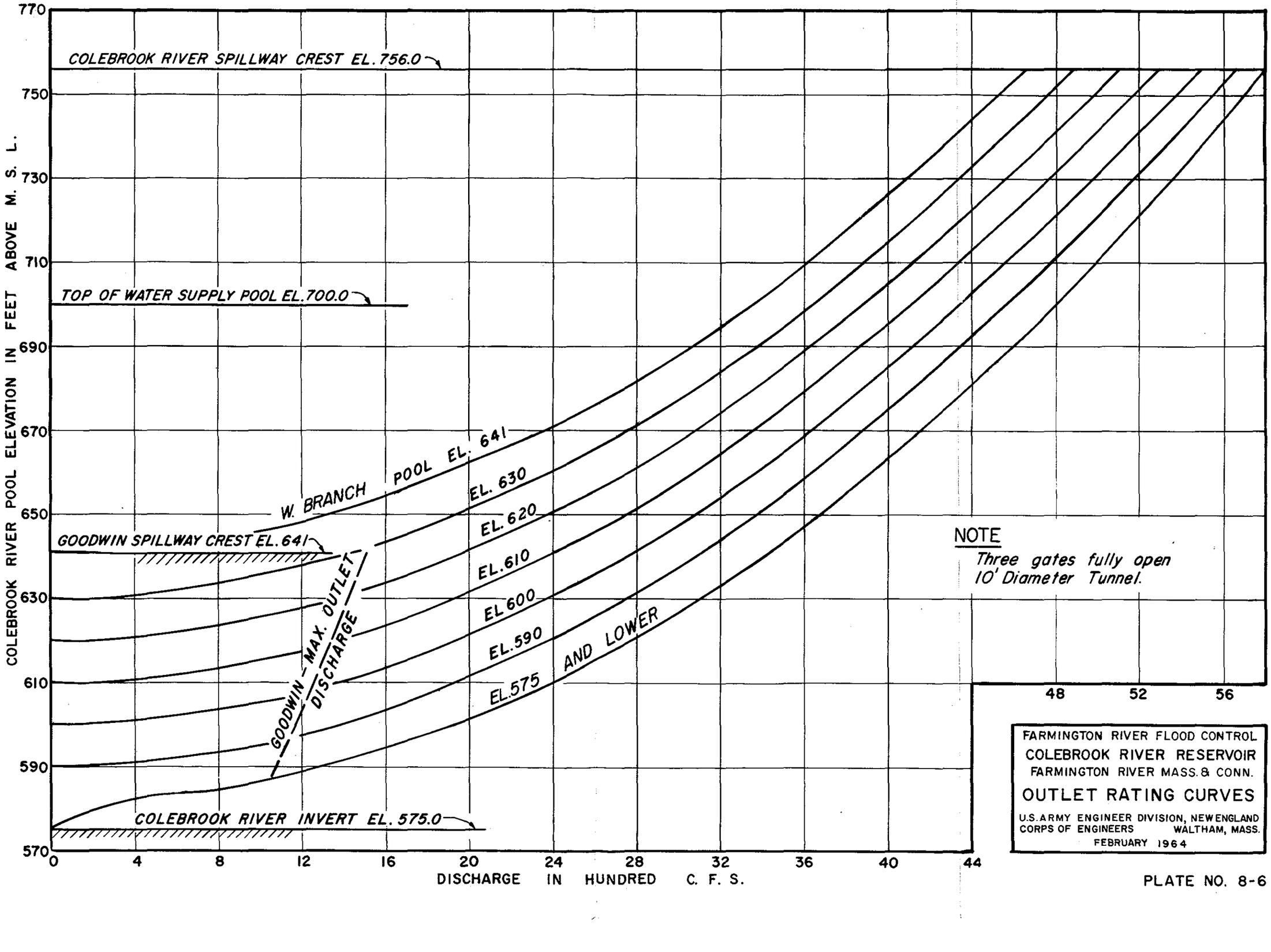
8

PLATE NO. 8-5



NOTE

Three gates fully open 10' Diameter Tunnel.

FARMINGTON RIVER FLOOD CONTROL
COLEBROOK RIVER RESERVOIR
FARMINGTON RIVER MASS. & CONN.

OUTLET RATING CURVES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
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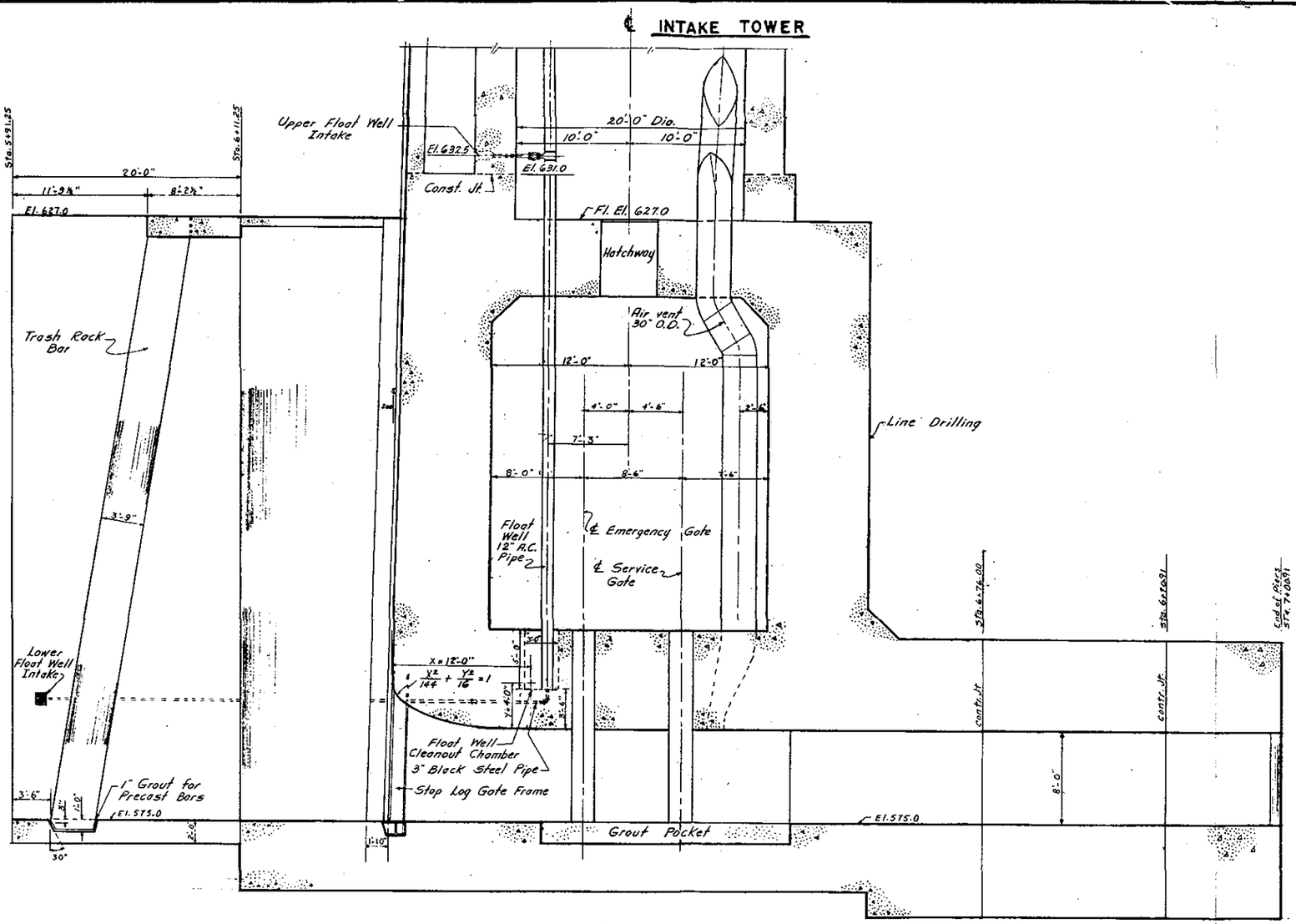
FEBRUARY 1964

PLATE NO. 8-6

CORPS OF ENGINEERS — U. S. ARMY



SECTION - ELEV. 575.0 TO ELEV. 627.0

SCALE: 1/4" = 1'-0"

GRAPHIC SCALE 0 4' 8' — 1/4"=1'-0"

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
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WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:

CHIEF, SECTION

REVIEWED:

PROJECT ENGINEER

APPROVED:

CHIEF, DESIGN BRANCH

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER DAM
INTAKE TOWER
SECTION - ELEV. 575.0 TO ELEV. 627.0
W. BR. FARMINGTON RIVER CONN. - MASS.

APPROVED: DATE:

CHIEF, ENGINEERING DIVISION

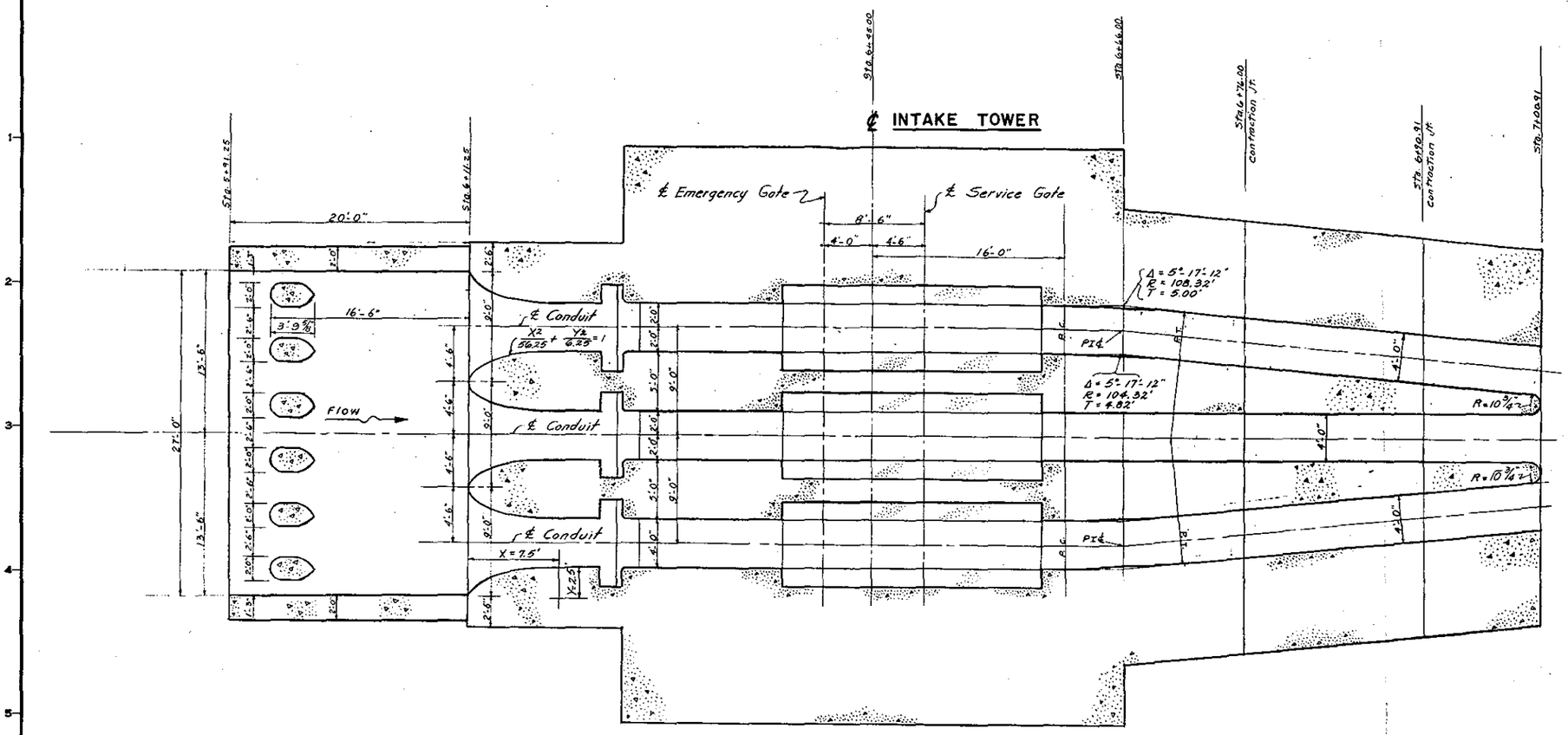
SCALE: 1/4" = 1'-0" SPEC. NO. CIV. ENG. 19-016-

DRAWING NUMBER

SHEET

PLATE NO. 8-7

CORPS OF ENGINEERS — U. S. ARMY



PLAN AT ELEV. 575.0
SCALE: 1/4"=1'-0"

GRAPHIC SCALE
1/4"=1'-0"
4' 0 4' 8'

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WALTHAM, MASS.

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APPROVED:
CHIEF, DESIGN BRANCH

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER DAM
INTAKE TOWER
PLAN AT ELEV. 575.0
W. BR. FARMINGTON RIVER CONN. - MASS.

APPROVED: DATE:
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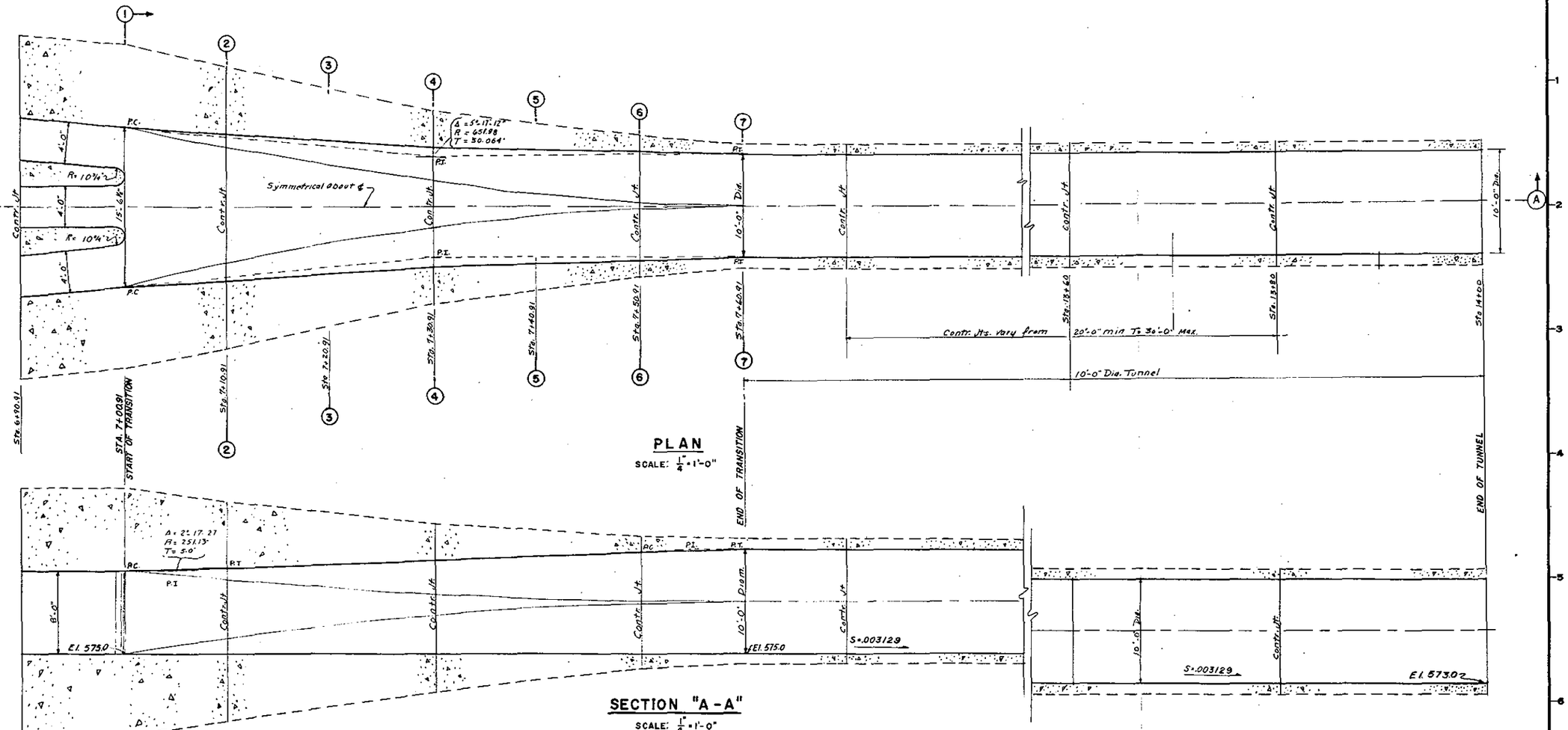
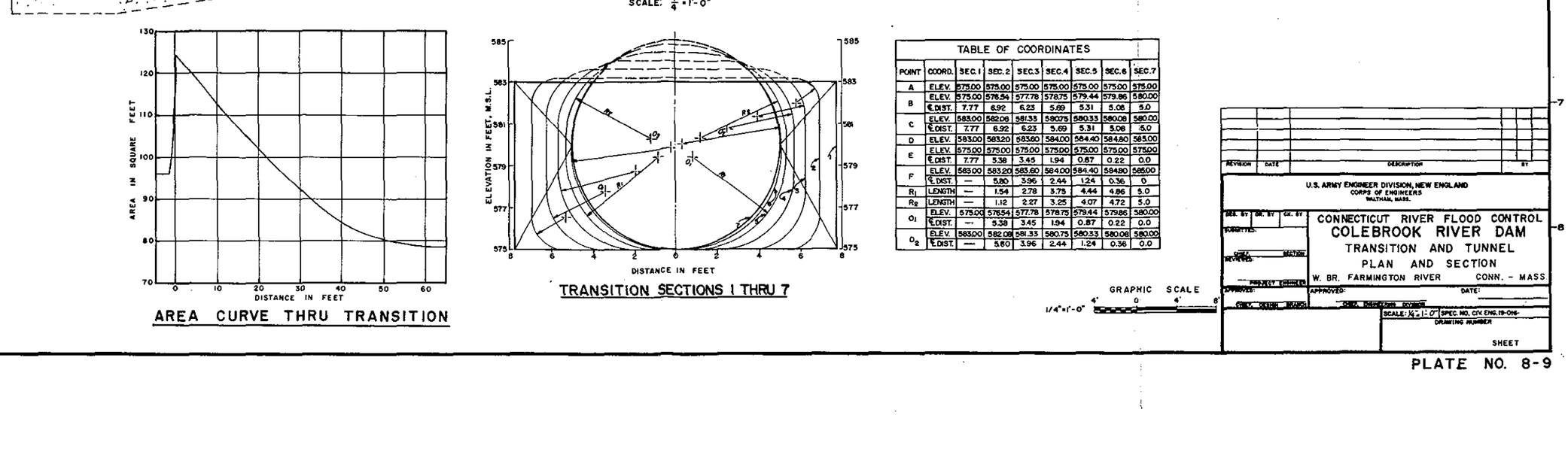
PLATE NO. 8-8

CORPS OF ENGINEERS — U. S. ARMY



PLAN

SCALE: 1/4" = 1'-0"



SECTION "A-A"

SCALE: 1/4" = 1'-0"

AREA CURVE THRU TRANSITION

TRANSITION SECTIONS 1 THRU 7

TABLE OF COORDINATES

POINT	COORD.	SEC.1	SEC.2	SEC.3	SEC.4	SEC.5	SEC.6	SEC.7
A	ELEV.	575.00	575.00	575.00	575.00	575.00	575.00	575.00
B	ELEV.	575.00	576.54	577.78	578.75	579.44	579.86	580.00
	℄ DIST.	7.77	6.92	6.23	5.69	5.31	5.08	5.0
C	ELEV.	583.00	582.08	581.35	580.75	580.33	580.08	580.00
	℄ DIST.	7.77	6.92	6.23	5.69	5.31	5.08	5.0
D	ELEV.	583.00	583.20	583.60	584.00	584.40	584.80	585.00
E	ELEV.	575.00	575.00	575.00	575.00	575.00	575.00	575.00
	℄ DIST.	7.77	5.38	3.45	1.94	0.87	0.22	0.0
F	ELEV.	583.00	583.20	583.60	584.00	584.40	584.80	585.00
	℄ DIST.	—	5.80	3.96	2.44	1.24	0.36	0
R_1	LENGTH	—	1.54	2.78	3.75	4.44	4.86	5.0
R_2	LENGTH	—	1.12	2.27	3.25	4.07	4.72	5.0
O_1	ELEV.	575.00	576.54	577.78	578.75	579.44	579.86	580.00
	℄ DIST.	—	5.38	3.45	1.94	0.87	0.22	0.0
O_2	ELEV.	583.00	582.08	581.35	580.75	580.33	580.08	580.00
	℄ DIST.	—	5.80	3.96	2.44	1.24	0.36	0.0

GRAPHIC SCALE

1/4"=1'-0" 4' 0 4' 8'

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:

CHIEF, SECTION

REVIEWED:

PROJECT ENGINEER

APPROVED:

CHIEF, DESIGN BRANCH

APPROVED: DATE:

CHIEF, ENGINEERING DIVISION

CONNECTICUT RIVER FLOOD CONTROL
COLEBROOK RIVER DAM
TRANSITION AND TUNNEL
PLAN AND SECTION
W. BR. FARMINGTON RIVER CONN. - MASS.

SCALE: 1/4" = 1'-0" | SPEC. NO. CIV. ENG. 19-016-

DRAWING NUMBER

SHEET

PLATE NO. 8-9