UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE OUTLET TUNNEL-- SPRING CREEK DAM-- PAONIA PROJECT

Hydraulic Laboratory Report No. Hyd. 320

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

August 31, 1951

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Laboratory Report No. Hyd-320
Hydraulic Laboratory
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Reviewed by: J. W. Ball
August 31, 1951

Subject: Hydraulic model studies of the outlet tunnel--Spring Creek Dam--Paonia Project

PURPOSE

To study the hydraulic characteristics of the outlet tunnel between the jet-flow regulating gate, Station 7+28.76, and the intersection of the rectangular outlet and the circular spillway tunnels, and to determine a proper design of this tunnel based on the results of the model study.

CONCLUSIONS

1. An outlet tunnel with dimensions as shown in Figure 3 will satisfactorily handle the outlet discharge at Spring Creek Dam.

2. A subatmospheric pressure of about 9 feet of water will occur over a small area of the tunnel floor 8 feet downstream from the gate when the gate is 40 to 50 percent open and with the reservoir at elevation 6774. It is believed this condition will not damage the concrete lining of the tunnel.

3. The four air vents shown in Figure 3 are ample and advantageously placed.

4. The jet flow regulating gate capacity for various gate openings is as shown in Figure 7.

RECOMMENDATIONS

1. Construct the outlet tunnel between the jet-flow gate and the spillway tunnel so that it enlarges in the direction of flow, is rectangular in cross section, and follows the parabolic curve $X^2 = -333.OY$ with

Note: This report covers the hydraulic model study on the preliminary design of the Outlet Works at Spring Creek Dam as shown in Specifications No. 2316, "Schedule, Specifications, and Drawing--Spring Creek Dam--Paonia Project, Colorado."

the origin at Station 7+29.93, floor elevation 6663.79, and roof elevation 6668.79 (Figure 3).

2. Aerate the tunnel at Station 7+30.76 with four 8-inch circular vents as shown in Figure 3.

INTRODUCTION

Spring Creek Dam on East Muddy Creek, about 17 miles northeast of Paonia, Colorado (Figure 1), is for flood control and to furnish supplemental irrigation water to the fertile valley of the north fork of the Gunnison River. The spillway, a morning-glory type with a crest diameter of 45 feet at elevation 6768.00, is located on the right side of the reservoir about 140 feet upstream from the axis of the dam. The spillway tunnel extends vertically to elevation 6745.00, through a 40° vertical bend and a reducing cone to elevation 6666.21 and a diameter of 15 feet, then through a 49° 0' 52" vertical bend to elevation 6648.0, and 814 feet to the outlet portal at elevation 6634.0. Normal reservoir water surface is at elevation 6768, and maximum water surface is at elevation 6774 (Figure 2).

The outlet works utilizes 390 feet of the 9-foot diameter diversion tunnel and merges with the spillway tunnel at the lower vertical bend (Figure 2). The inlet consists of a bellmouth entrance with a horizontal sill at elevation 6684.0, a 6-foot, 6-inch diameter throat, and a vertical bend enlarging uniformly to 9-foot diameter. The inlet structure will be formed as part of the tunnel plug at the inlet portal to the diversion tunnel. The outlet gate chamber consists of a bellmouth which reduces the tunnel diameter to 4 feet, a 48-inch ring follower emergency gate, and a 42-inch jet-flow regulating gate. A tunnel, rectangular in cross section, connects the gate chamber to the spillway tunnel.

This model study concerns the operation of the jet-flow regulating gate, flow through the rectangular tunnel and into the lower spillway bend, and aeration downstream from the gate. The operation of the spillway was not included in these tests as it is assumed that while the spillway is discharging, the outlet gate will be closed.

THE MODEL

A jet-flow gate with a 5.65-inch diameter flow passage was available in the laboratory so the model was built on a scale of 1:7.43 to permit the use of this gate. The rectangular outlet tunnel downstream from the gate, and a portion of the circular spillway tunnel including the vertical bend into which the outlet tunnel discharged, was fabricated of transparent plastic (Figure 4-A). The model outlet tunnel was vented with four 1.075-inch circular openings 2.35 inches downstream from the gate. The spillway tunnel downstream from the bend (representing about 180 feet of the prototype structure) was formed of sheetmetal; the top half of the tunnel was removed for the first 8 feet to allow observation of the flow, the remaining 16 feet represented the circular tunnel because the flow from the outlet climbed the walls of the spillway tunnel in this section. Figure 5-A is a view looking downstream into the circular tunnel.

The nonrising stem of the model gate was so threaded that 100 turns of the operating handle moved the gate leaf 100 percent of its travel. A counting mechanism was geared to the operating handle to record the number of turns and provide an accurate and rapid setting of any desired gate opening (Figure 4-B).

Water was delivered to the model through a 20-foot section of 6-inch pipe. The model did not include facilities for flow in the spillway tunnel above the outlet opening.

Readings from a piezometer in the supply pipe 6 inches upstream from the model gate were used in determining representative reservoir elevations. Thirteen piezometers were located on the tunnel floor center line to permit the determination of pressures in this portion of the structure.

THE INVESTIGATION

Test Procedure

Flow was observed in the outlet tunnel for a full range of gate openings and for reservoir elevation from 6684, the elevation of the sill of the inlet structure, to elevation 6785, 11 feet above maximum reservoir elevation. In the prototype there will be flow from the morning-glory spillway when the reservoir is above elevation 6768; however, such flow was not included in the model tests. In the recommended design, piezometers were installed to determine the pressures on the floor of the outlet tunnel.

Preliminary Design

In the preliminary design the floor of the outlet tunnel was parabolic, following the curve $X^2 = -450.86Y$, origin at Station 7+29.93 and elevation 6663.79. When the jet-flow gate was opened 85 percent or more, and the reservoir was at elevation 6779, 113 feet above the center line of the gate, the under nappe of the jet cleared the floor of the tunnel. For smaller gate openings and/or lower reservoir elevations, the jet impinged on the tunnel floor, spread out, and climbed the vertical walls of the outlet tunnel. When the jet cleared the outlet tunnel floor and fell into the spillway tunnel, the water climbed the sides of the spillway tunnel similar to the flow shown in Figure 5-A. This flow would probably not damage the spillway. When the flow spread out on the floor of the outlet tunnel and climbed the vertical walls, the rushing water created a large air demand. It appeared that the tunnel floor should be curved more sharply downward to decrease the range of flow at which the jet spread out in the outlet tunnel; such a change would decrease the possibility of severe subatmospheric pressures at partial gate openings.

Effect of Changing the Floor Shape

The floor of the outlet tunnel was changed to the curve $X^2 = -320.OY$; the side walls and roof were not changed. With this design the jet cleared the outlet tunnel floor when the gate was full open and the reservoir was above elevation 6746.0. The discharge with this gate opening and reservoir elevation was about 83 percent of that when the jet just touched the outlet tunnel floor with the preliminary design. The amount of air drawn in through the air vents was not measured, but the tunnel appeared to be adequately aerated under all conditions of gate opening and reservoir elevation.

Recommended Design

The outlet tunnel with a floor following the curve $X^2 = -320.OY$ was acceptable hydraulically, but the floor of the tunnel intersected the spillway tunnel in the vertical bend. Since the spillway flow will impinge on the invert of the bend, it would be desirable to have the floor of the outlet tunnel enter the spillway tunnel at or above the intersection of the converging section and the vertical bend of the spillway. An outlet tunnel with a floor profile following the curve $X^2 = -333.OY$ would enter the spillway at the desired elevation and have practically the same hydraulic characteristics as the previous design. The portion of the outlet tunnel between the jet-flow gate and the spillway tunnel was reshaped to this curvature and piezometers were installed on 3-inch centers (model distance) on the center line of the tunnel floor (Figure 3).

The flow in the outlet tunnel was satisfactory for any combination of reservoir elevation and gate opening. Figure 5-B shows the flow into the spillway bend with the gate full open and the jet just touching the outlet tunnel floor; Figure 6-A shows the flow touching the vertical side walls, and Figure 6-B shows the flow climbing the side walls to the roof of the outlet tunnel. The tunnel air vents were adequate and properly placed. When the reservoir was at elevation 6774 a maximum positive pressure of about 8 feet of water occurred on the outlet tunnel floor 2-1/2 feet downstream from the jet-flow gate when the gate was opened up to 40 percent, and a maximum subatmospheric pressure of 9 feet of water occurred 8 feet downstream when the gate was 40 to 50 percent open (Figure 3).

FIGURE 1
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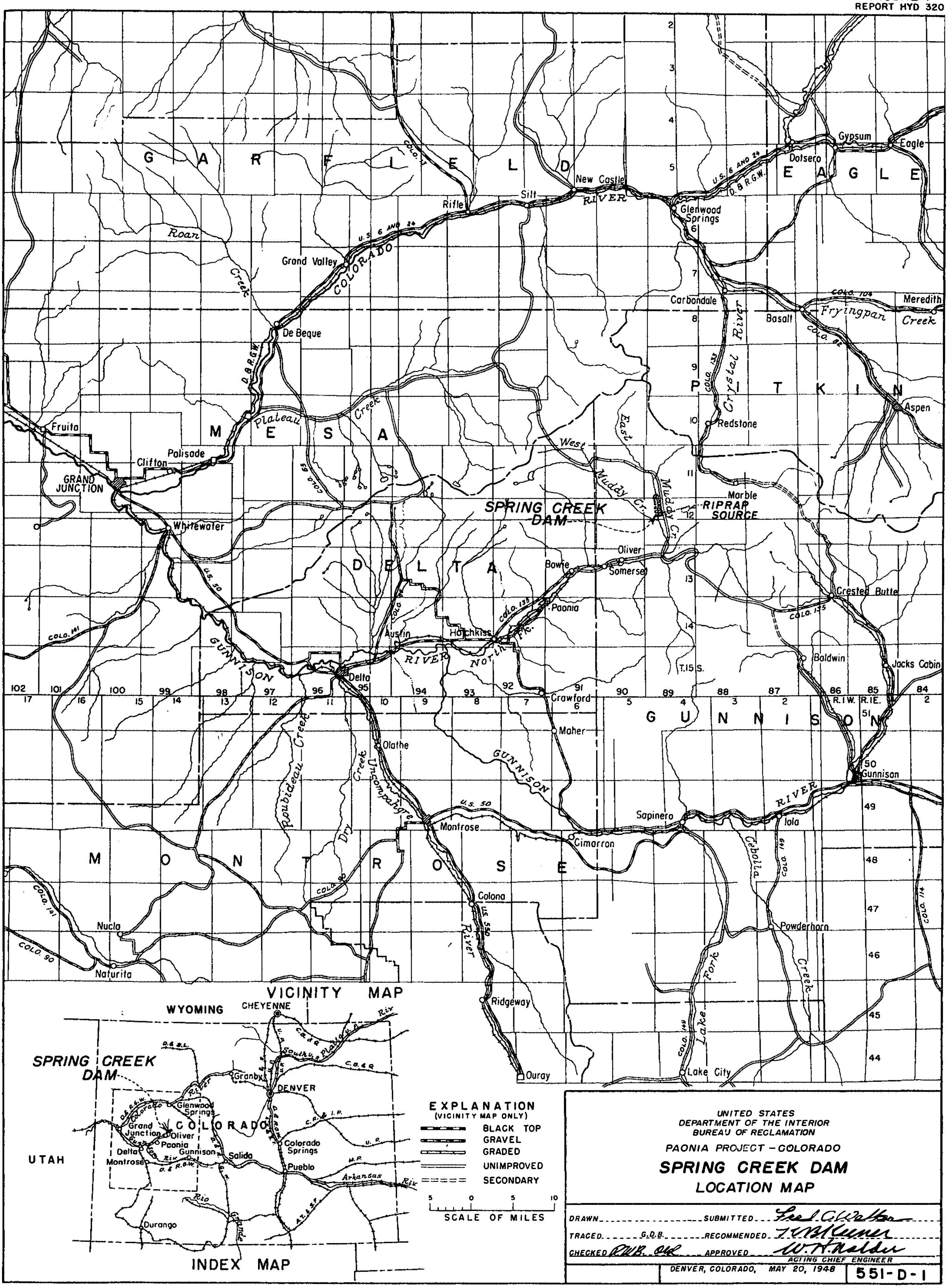

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SPRING CREEK DAM
LOCATION MAP

DRAWN ______ SUBMITTED *Fred C. Walker*
TRACED G.O.B. RECOMMENDED *[signature]*
CHECKED *RWB. OW* APPROVED *W. H. Nalder*
ACTING CHIEF ENGINEER

DENVER, COLORADO, MAY 20, 1948 | 551-D-1

FIGURE 2
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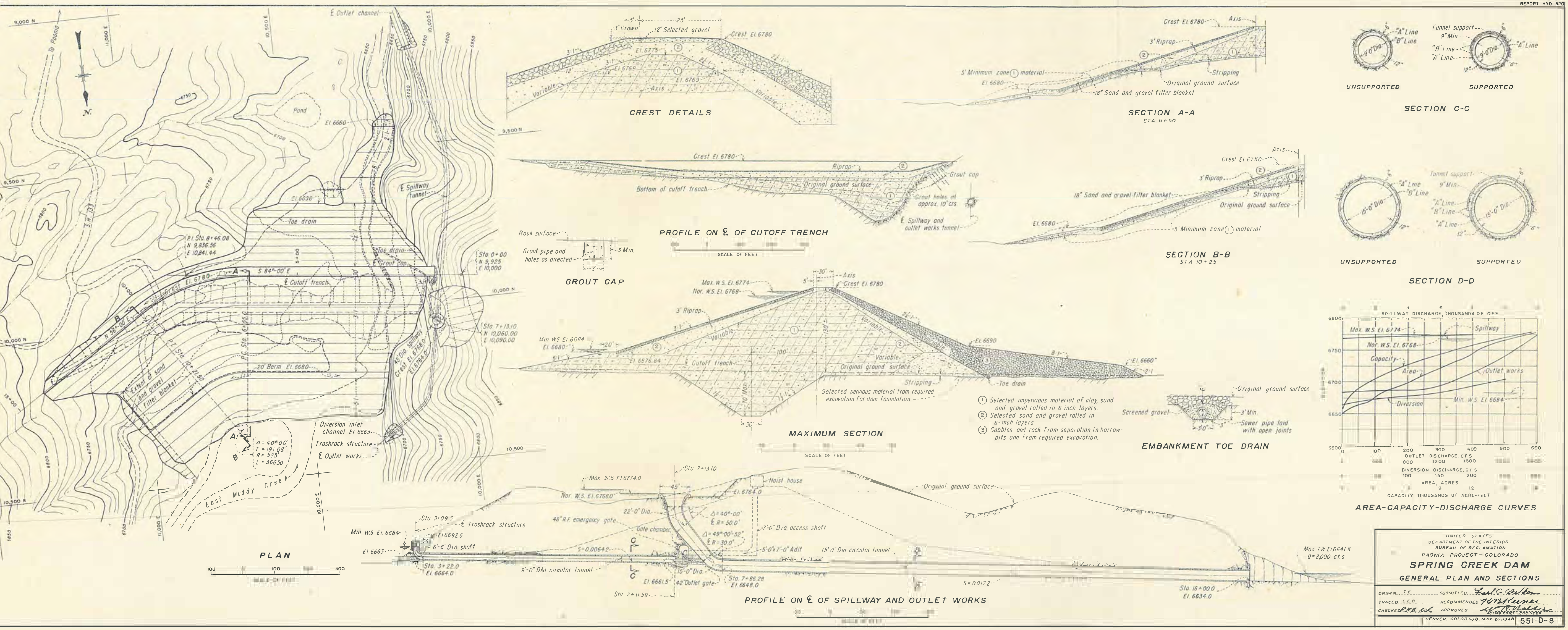
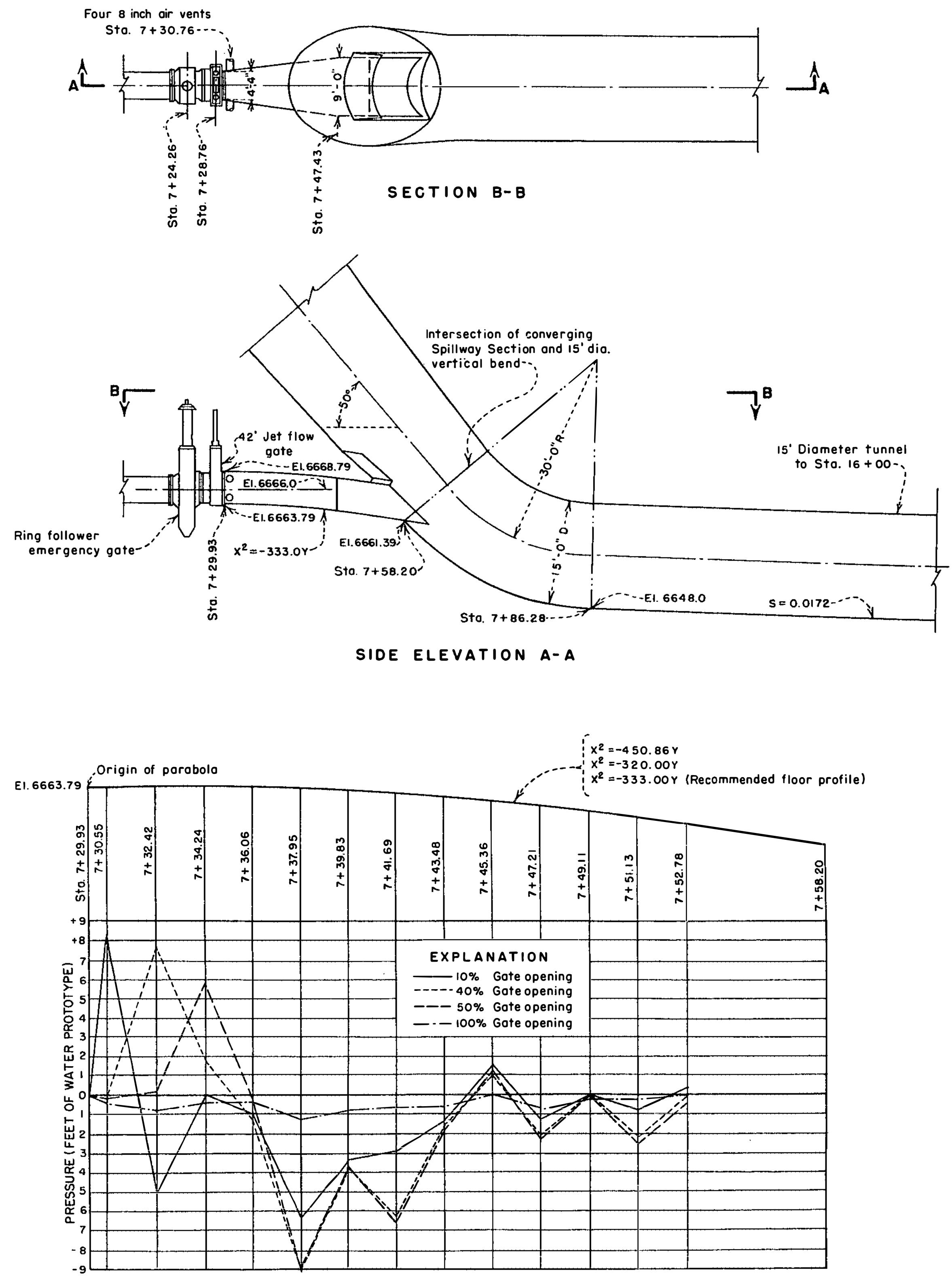




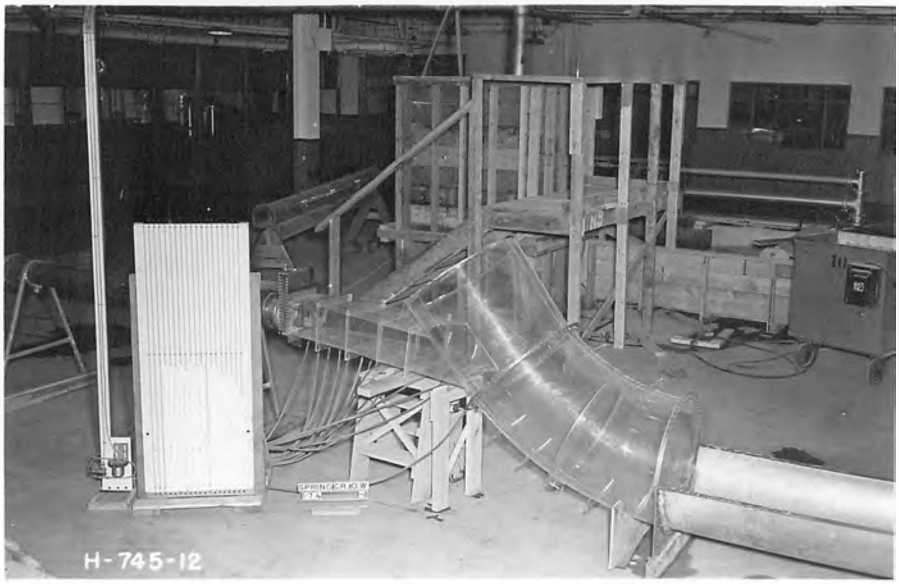
OUTLET TUNNEL FLOOR PRESSURES
FOR MAX. RESERVOIR ELEV. 6774
RECOMMENDED DESIGN

PAONIA PROJECT - COLORADO

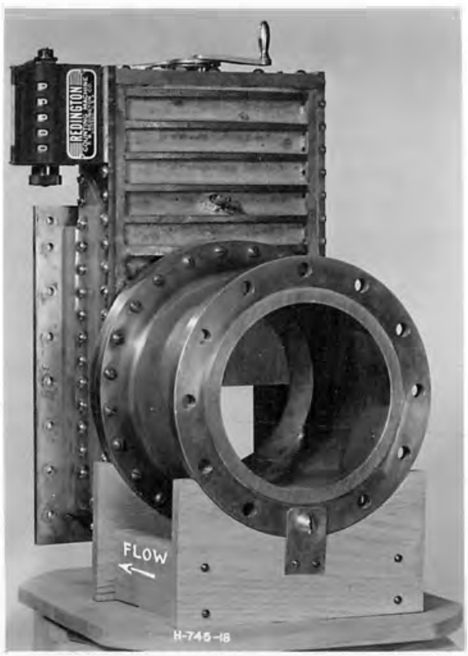
SPRING CREEK DAM

RECOMMENDED OUTLET TUNNEL AND FLOOR PRESSURES

MODEL SCALE 1:7.43



A. The Model, Recommended Design



B. Jet Flow Regulating Gate, 6-inch Model
Gate 50 Percent Open

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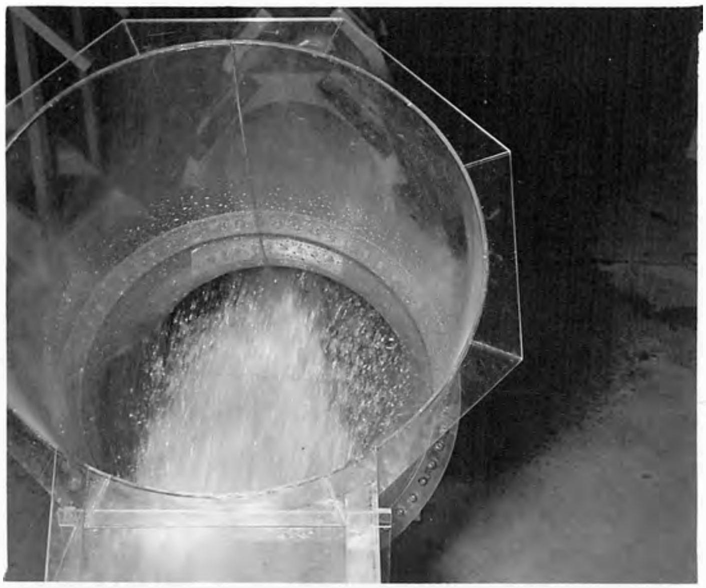
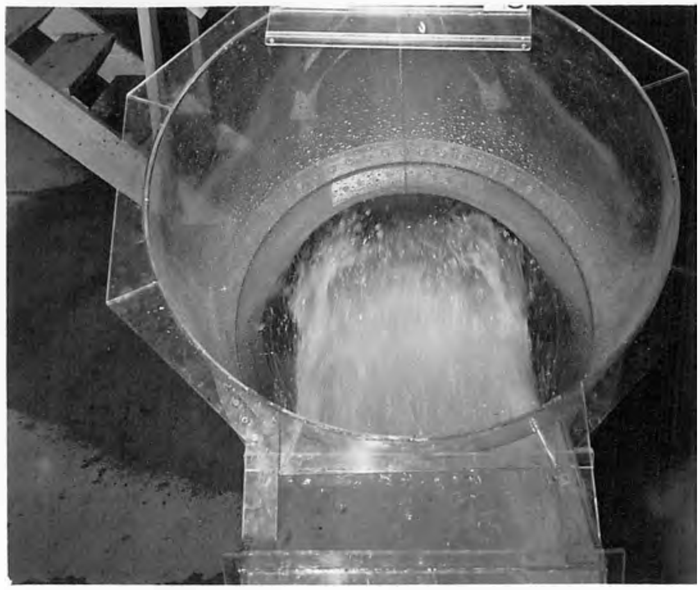
A. Looking Downstream Into the Spillway Tunnel Jet Flow Gate 100 Percent Open Reservoir Elevation 6754



B. Looking Downward Into the Spillway Bend Jet Flow Gate 100 Percent Open Reservoir Elevation 6746

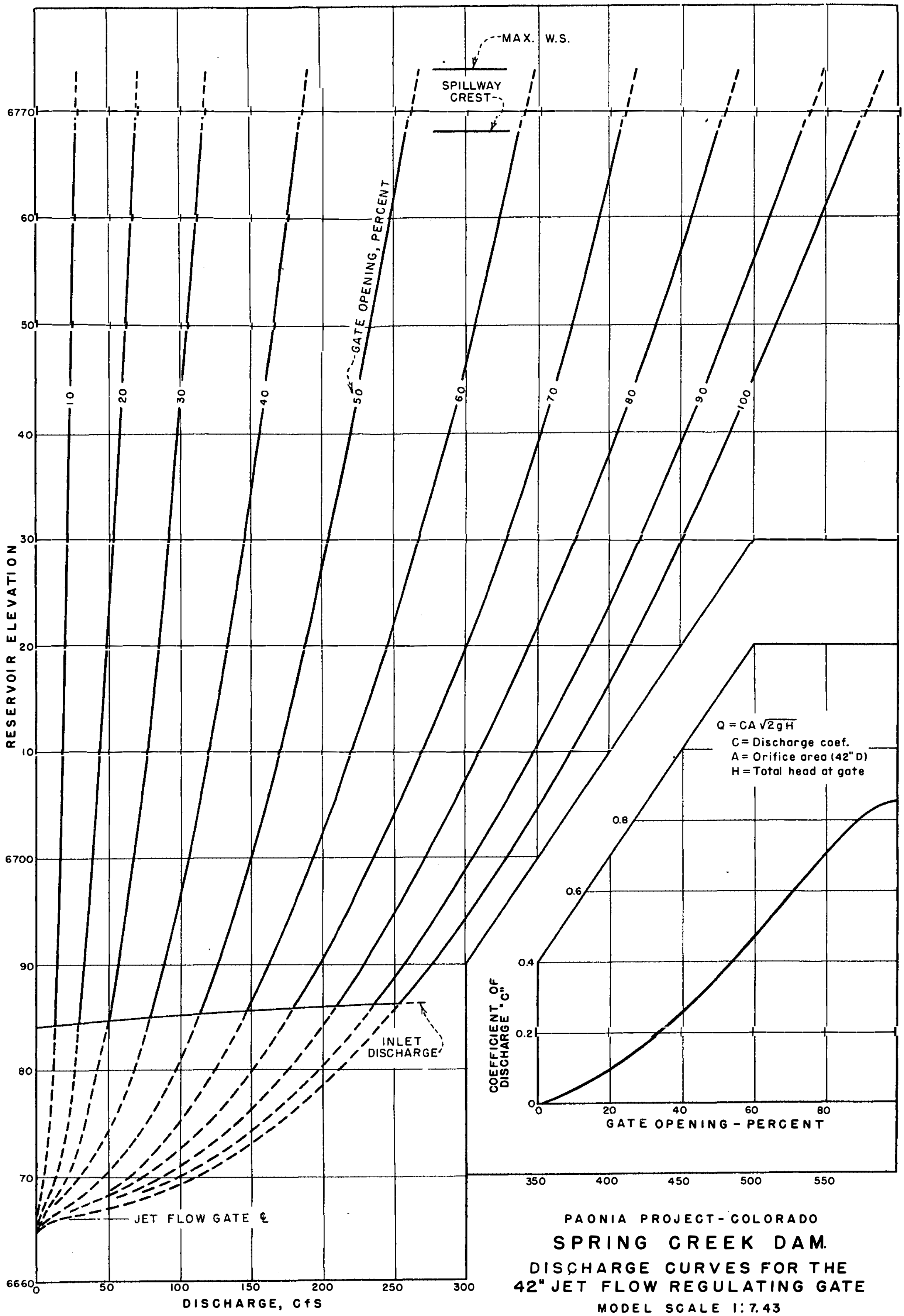
Paonia Project, Colorado
SPRING CREEK DAM
Recommended Design



A. Looking Downward into the Spillway
Bend Jet Flow Gate 70 Percent
Open Reservoir Elevation 6768

B. Looking Downward into the Spillway
Bend Jet Flow Gate 100 Percent
Open Reservoir Elevation 6686

Paonia Project, Colorado
SPRING CREEK DAM
Recommended Design



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SPRING CREEK DAM

DISCHARGE CURVES FOR THE
42" JET FLOW REGULATING GATE

MODEL SCALE 1:7.43