UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF SHERMAN DAM OUTLET WORKS

Hydraulic Laboratory Report No. Hyd-455

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

September 28, 1959

CONTENTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Denver, Colorado
September 28, 1959

Laboratory Report No. Hyd-455
Prepared by: G. L. Beichley
Edited by: A. J. Peterka
Reviewed by: J. W. Ball
Submitted by: H. M. Martin

Subject: Hydraulic model studies of Sherman Dam outlet works

SUMMARY

Hydraulic model studies of the Sherman Dam outlet works were conducted on a 1:20 scale model to develop the hydraulic design of the outlet works stilling basin.

The studies showed the preliminary basin design to be adequate for the design flow from two gates, but inadequate for an emergency operating condition in which the normal canal flow is discharged through only one of the two gates. For the latter operating condition, the flow was on the verge of sweeping from the basin without the formation of a hydraulic jump within the basin. As a remedy, the center dividing wall was shortened approximately 10 feet, and the basin floor was lowered 2 feet in elevation. In this recommended design, no significant erosion occurred in the canal bed downstream from the basin, and wave action along the canal banks was judged to be tolerable. Wave suppressors were tested, and it was found that the waves could be reduced considerably. Based on judgment, it was decided that a wave suppressor would not be necessary as part of the prototype structure. If a suppressor is required, it can be constructed later.

ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Spillway and Outlet Works Section and the Hydraulic Laboratory during the period from April 1959, to May 1959.

INTRODUCTION

Sherman Dam, part of the Missouri River Basin Project, is located on Oak Creek about 20 miles northwest of Grand Island, Nebraska, Figure 1. The dam, Figure 2, is an earthfill structure approximately 4,000 feet long at the crest, approximately 100 feet high from the

foundation, and approximately 600 feet wide at the base of the maximum cross section, and 30 feet wide at the crest. Its purpose is to provide irrigation water and flood protection. A spillway and an outlet works are used for water discharge.

The spillway, Figure 3, consists of an 8-foot-diameter, concrete-lined conduit discharging into a concrete stilling basin designed for a maximum discharge of 1,095 cfs. No hydraulic model tests were performed on this structure.

The outlet works, Figures 4 and 5, consists of a concrete intake structure, a 96-inch steel pipe, a concrete gate chamber with a 6- by 7-foot, 6-inch high pressure emergency gate, a 90-inch steel outlet pipe, a concrete anchor block and control house containing a steel Y-branch pipe with two 4- by 5-foot high pressure gates, and a concrete stilling basin. The outlet works is designed to discharge approximately 1,600 cfs at reservoir elevation 2169.7 into an earth-lined canal 32 feet wide at its base. Tail water elevation in the canal will be approximately 2104.5. The first 67 feet of the canal downstream from the basin is to be riprapped. The outlet works stilling basin and a section of the canal extending downstream from the basin are the features studied in this investigation.

THE MODEL

The outlet works model, Figure 6, is a 1:20 scale reproduction of the prototype. The model included the two 4- by 5-foot high pressure slide gates, the stilling basin, and about 75 feet of canal section extending downstream from the basin. The gate assemblies were constructed of sheet metal. The brass gate leaves were attached to threaded brass rods for lowering and raising the gate to any position. The stilling basin was of plywood construction, with one wall made from 3/8-inch transparent plastic for observing the flow within the basin. The canal was molded in sand for the first tests but was later covered with size-selected rocks to simulate the prototype riprap.

In operating the model, the discharge and the gate opening were regulated in accordance with the computed curves in Figures 7 and 8. For one gate operation, the right valve was always operated so that the flow could be observed through the transparent wall. The tail water elevation was regulated in accordance with the anticipated tail water curve in Figure 9. The tail water elevation was measured using a point gage located in the canal approximately 70 feet downstream from the stilling basin. Water surface fluctuations in the canal were measured using an inch rule at a spot near the right bank about 60 feet downstream from the stilling basin.

THE INVESTIGATION

The primary purpose of the investigation was to develop the hydraulic design of the outlet works stilling basin. To accomplish this, it was necessary to study the flow for a wide range of operating conditions within the basin and in the canal joining the downstream end of the basin.

Preliminary Basin

The preliminary stilling basin was similar to the recommended basin shown in Figure 4, with the exceptions that the center training wall was 11 feet 6 inches shorter than shown, and the apron was at elevation 2088 instead of 2086, as shown.

The preliminary basin was designed for two 4- by 5-foot gates 100 percent open discharging 1,675 cfs at a total head of approximately 65 feet at the gates. The Froude number of the flow entering the basin at the upstream end of the horizontal apron is approximately 6.5. Other possible operating conditions, combinations of head and gate opening, are shown by the discharge curves in Figures 7 and 8. The tail water elevation for the various discharges is given in Figure 9.

The preliminary basin performed very well in discharging the normal canal flow of 960 cfs, Figure 10, whether the flow was at maximum gate opening or maximum head. For discharges near the maximum design flow, the basin performance was still good, Figure 11; however, at times the water surface downstream from the basin appeared to be too rough for the unprotected earth banks of the canal. A wave suppressor, 15 feet long installed at elevation 2098 in the downstream portion of the stilling basin, Figure 11, reduced the water surface fluctuation in the canal. Water surface fluctuations were measured along the canal bank 60 feet downstream from the basin. The wave suppressor improved the water surface for all operating conditions; in general, the suppressor reduced the water surface fluctuations by one-half, Figure 12. However, since the canal banks were to be riprapped for a distance of about 67 feet beyond the end of the basin, it was decided that a wave suppressor would not be necessary.

A scour test, Figure 13, showed that the basin performed well in preventing excessive erosion of the sand channel bottom after 2 hours of model operation. The discharge was varied from 400 to 1,515 cfs at maximum head by adjusting the gate opening during the test.

Sweepout tests were conducted by maintaining the discharge constant while decreasing the gate opening; or, in other words, by increasing the head at the gates above the computed values shown in Figure 14. For two-gate operation, the margin of safety was ample for

all ranges of operation. For one-gate operation, the factor of safety was found to be small for small discharges; for discharges of 750 cfs or more at maximum head, the jump swept out of the upstream portion of the basin, Figure 14. One-gate operation is not normal, but emergency operating conditions may require the use of a single gate for short periods. Because of the danger of jump sweepout, the basin was modified to provide more factor of safety for one-gate operation.

The Recommended Design

To maintain the hydraulic jump in the basin during one-gate operation, two modifications of the preliminary basin were made. First, the center wall was shortened approximately 10 feet. This helped to stabilize the jump and provided a safety factor of about 2 percent in gate opening for maximum discharge at maximum head from one gate, Figure 14. Second, the elevation of the basin floor was then lowered 2 feet to elevation 2086. This arrangement, the recommended design provided a factor of safety of approximately 30 percent in gate opening for maximum discharge from one gate at maximum head as shown in Figure 14.

The sweepout safety factor in terms of tail-water elevation was investigated, Figure 15. For the design flow from two gates, the tail water could be lowered 7 feet before the sweepout condition was reached. For the design flow from one gate, the tail water could be lowered 2 feet before sweepout from the upstream portion of basin was possible.

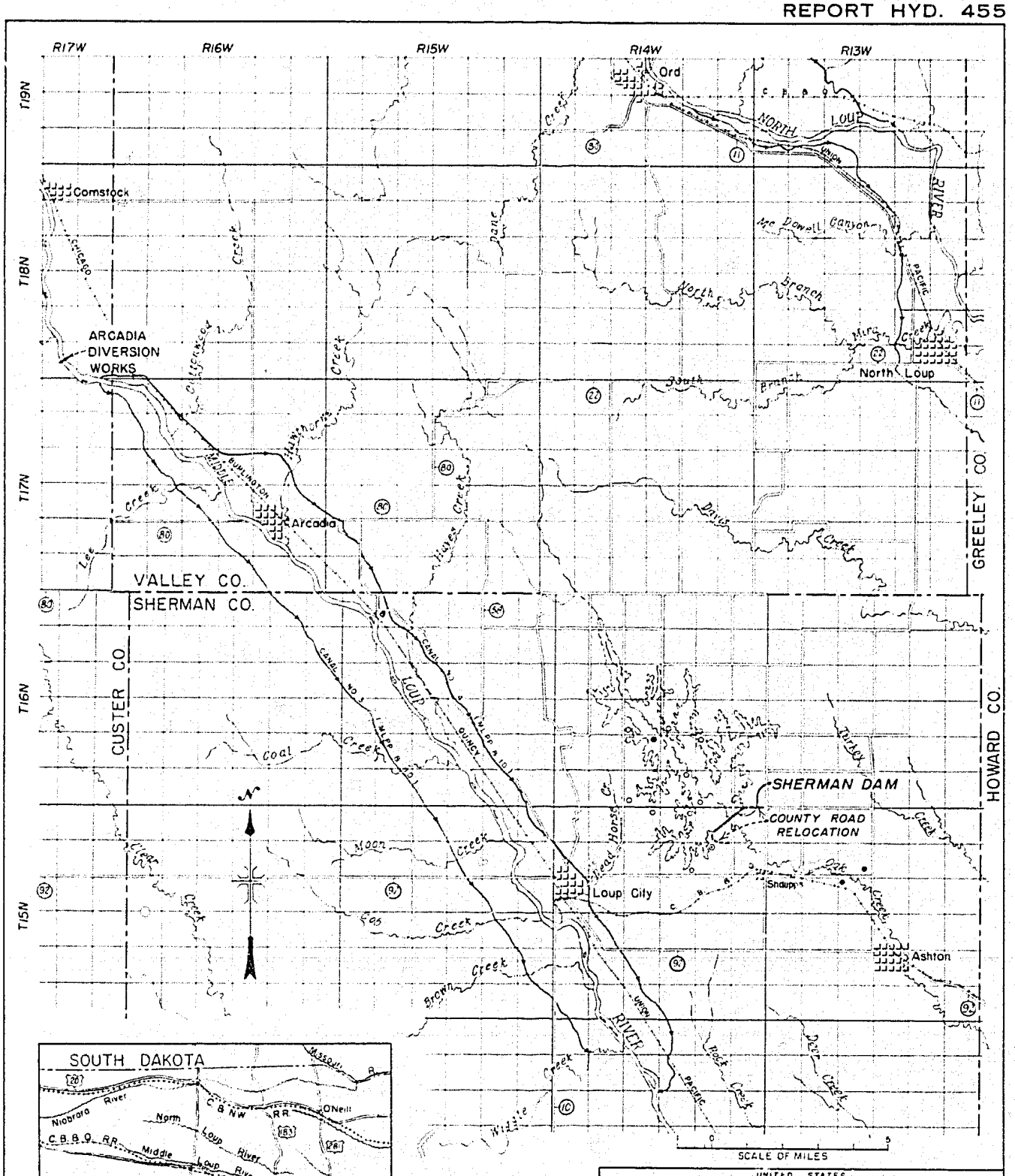
Water surface fluctuations to be expected along the canal banks for the various schemes tested are shown in Figures 16 and 17. The recommended design with the floor lowered 2 feet provided a smoother water surface than the preliminary design with the wall shortened. The wave suppressor further reduced the fluctuations when used with any of the designs tested.

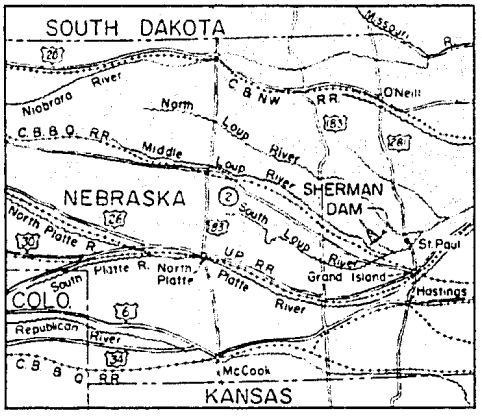
For the recommended design and maximum design flow, the addition of the wave suppressor reduced the water surface fluctuations from 14 to 8 inches. For the normal flow passed through one gate, the suppressor reduced the fluctuations from 23 to 16 inches. However, with the suppressor in place, the water surface upstream from the suppressor became somewhat rougher.

To determine whether the suppressor was necessary in the prototype, the model canal banks were covered with riprap scaled to prototype sizes. The basin discharging flows ranging from 560 cfs to a maximum of 1,675 cfs through two gates and up to 990 cfs through one gate, Figures 18 through 21, produced no movement of riprap along the canal banks and very little movement on the canal bottom near the end of the basin after 4 hours of model operation. As the flow passed downstream,

the riprap had a tendency to reduce the waves and water surface fluctuations so that the disturbances at the end of the riprap were relatively minor. The suppressor was, therefore, determined to be unnecessary. However, a suppressor can be added later if prototype waves cause damage to the canal banks. The performance of the wave suppressor for 990 and 1,675 cfs is shown in Figure 22.

FIGURE 1
REPORT HYD. 455





KEY MAP

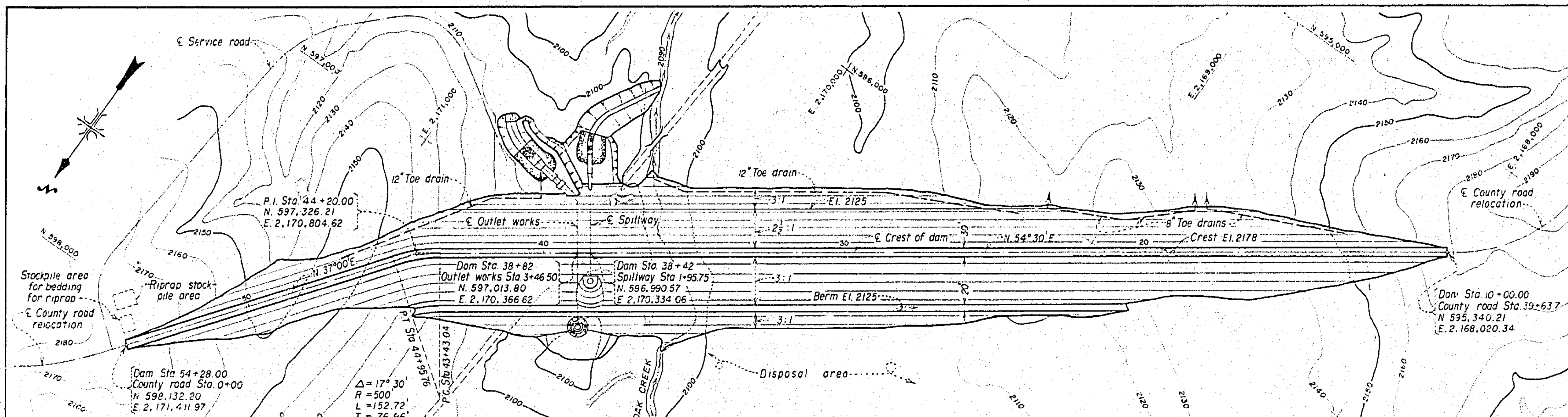
- ○ APPROXIMATE LOCATION OF FARM WELLS
- ● APPROXIMATE LOCATION OF IRRIGATION WELLS
- ⊙ WATER WELL FOR PILE TEST PROGRAM

NOTE: FOR DETAILS OF WELLS SEE TABLE IN SPECIFICATIONS

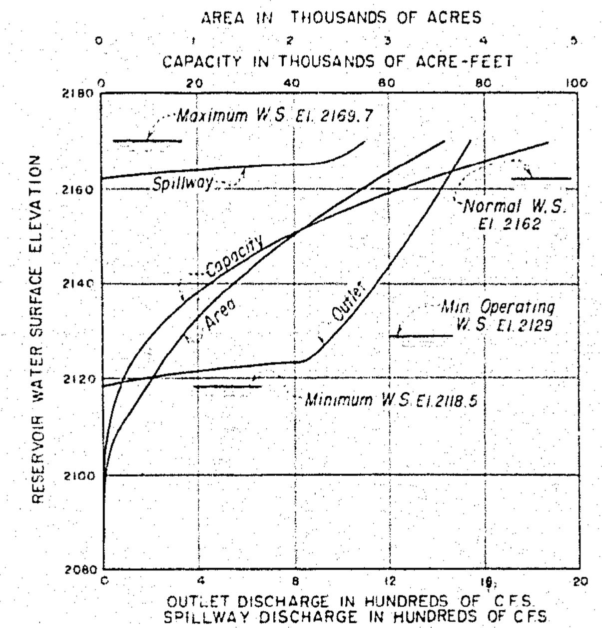
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
MIDDLE LOUP DIVISION – FARWELL UNIT – NEBRASKA

SHERMAN DAM
LOCATION MAP

DRAWN MLK	SUBMITTED	Edmund A. Olson
TRACED MLK	RECOMMENDED for ap'l	E. G. Paulsen
CHECKED BC	APPROVED	Grant Bloodgood
ST PAUL, NEBRASKA	NOVEMBER 20, 1958	707-729-1



GENERAL PLAN



AREA-CAPACITY-DISCHARGE CURVES

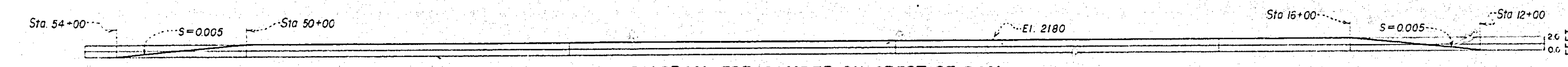
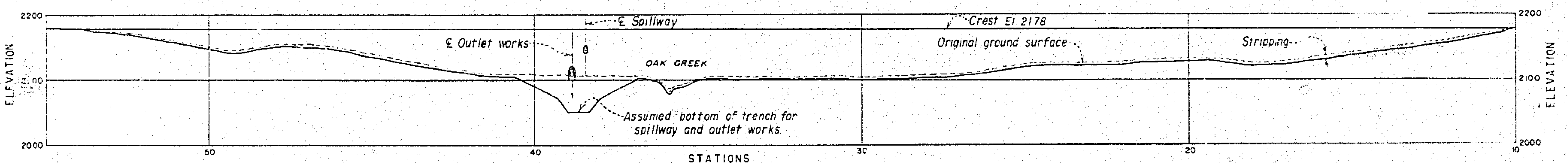
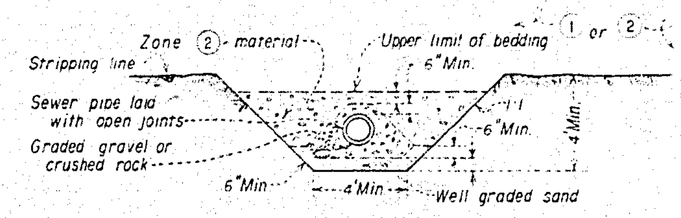


DIAGRAM FOR CAMBER ON CREST OF DAM



PROFILE ON ℄ CREST OF DAM



EMBANKMENT TOE DRAIN DETAIL

RESERVOIR STORAGE ALLOCATIONS

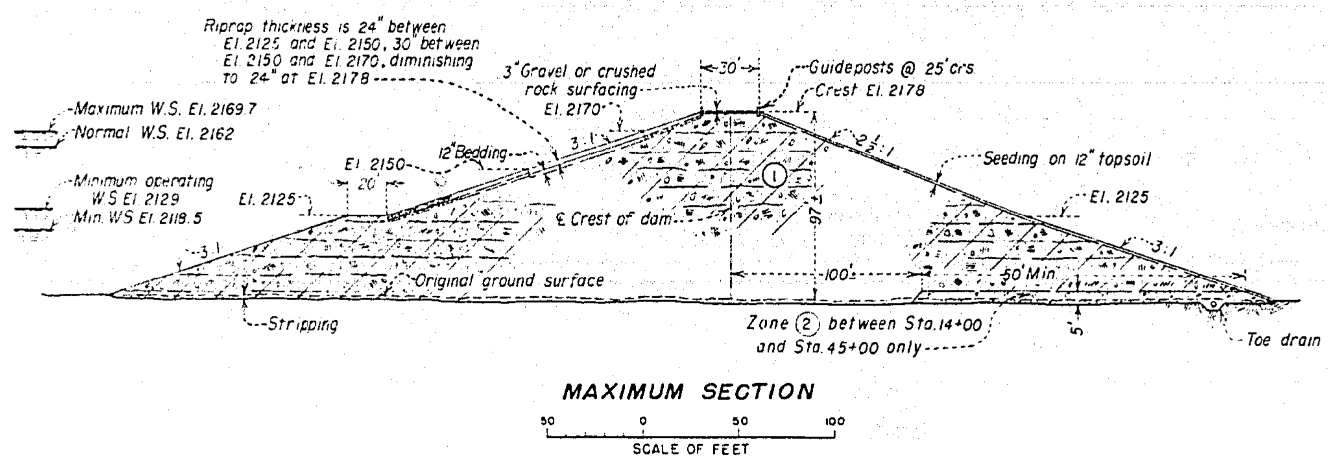
PURPOSE	ELEVATIONS	STORAGE ACRE - FEET
Conservation	El. 2129 to El. 2162	58,300
Inactive	El. 2118.5 to El. 2129	6,800
Dead	Streambed to El. 2118.5	4,000
Total Storage Capacity		69,100 *

*Includes an allowance of 10,000 a.f. for sediment

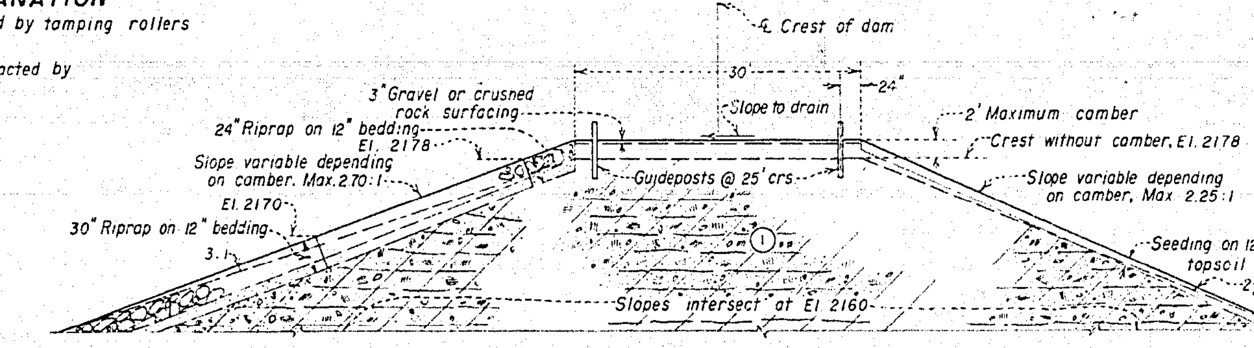
A surcharge of 24,300 a.f. (Maximum W.S. El. 2169.7) in combination with spillway capacity of 1,095 c.f.s. is provided to protect against a project flood having a peak of 6,125 c.f.s. with a 15-hour volume of 3,621 a.f. followed in 4 days by the inflow design flood having a peak of 37,000 c.f.s. with a 30-hour volume of 24,200 a.f.

EMBANKMENT EXPLANATION

(1) Selected clay, silt and sand compacted by tamping rollers to 6-inch layers.
(2) Sand and gravel or crushed rock compacted by crawler-type tractor to 12-inch layers.



MAXIMUM SECTION



CREST DETAIL AT MAXIMUM CAMBER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
MIDDLE LOUP DIVISION-FARWELL UNIT-NEBRASKA

SHERMAN DAM

GENERAL PLAN AND SECTIONS

DRAWN ..... SUBMITTED O. J. Larsen
TRACED ..... RECOMMENDED L. G. Puls
CHECKED ..... APPROVED Grant Bloodgood, ASST. COMM. AND CHIEF ENGINEER

DENVER, COLORADO, APRIL 30, 1959 | 707-D-9

FIGURE 3
REPORT HYD. 455

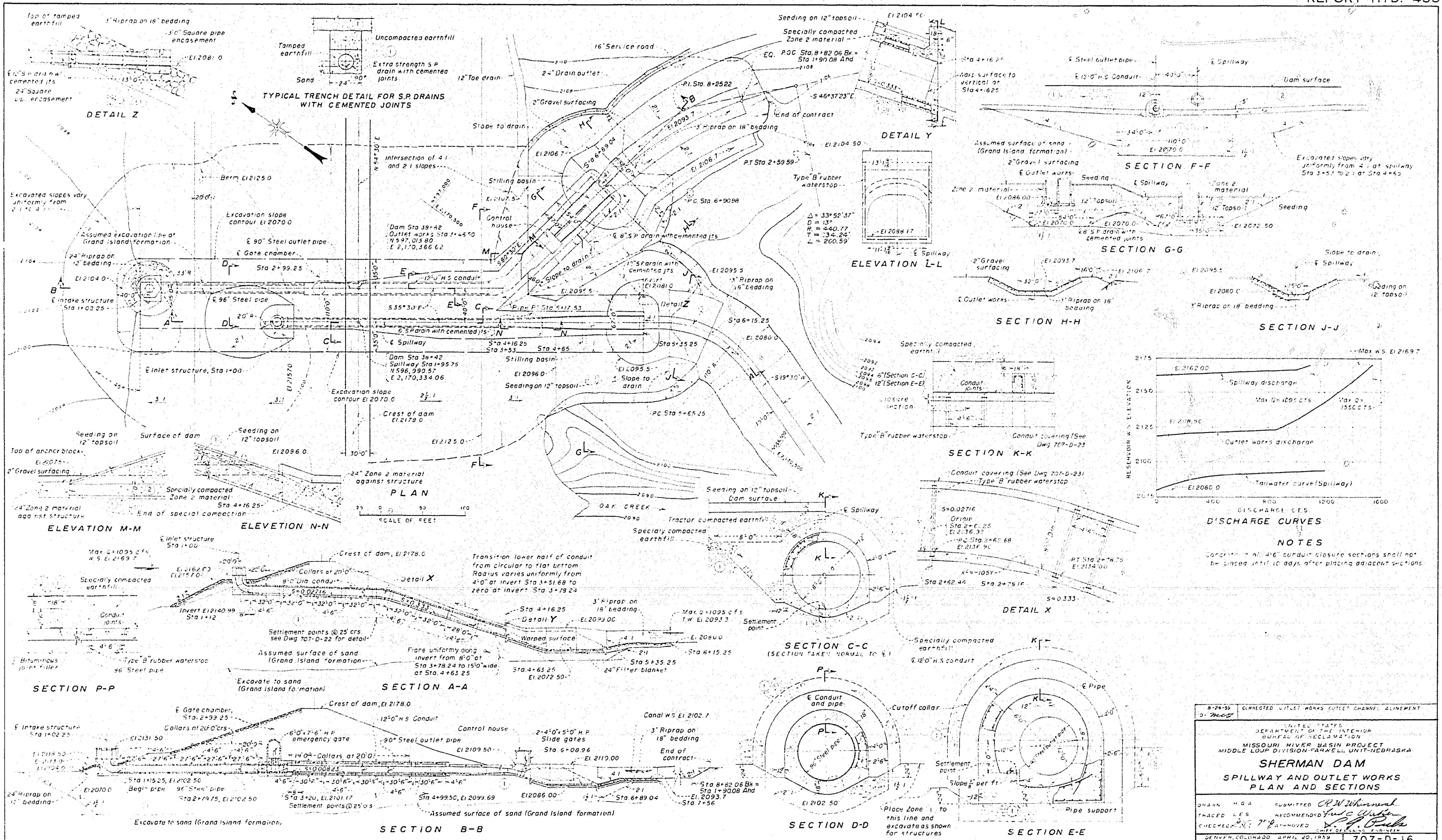
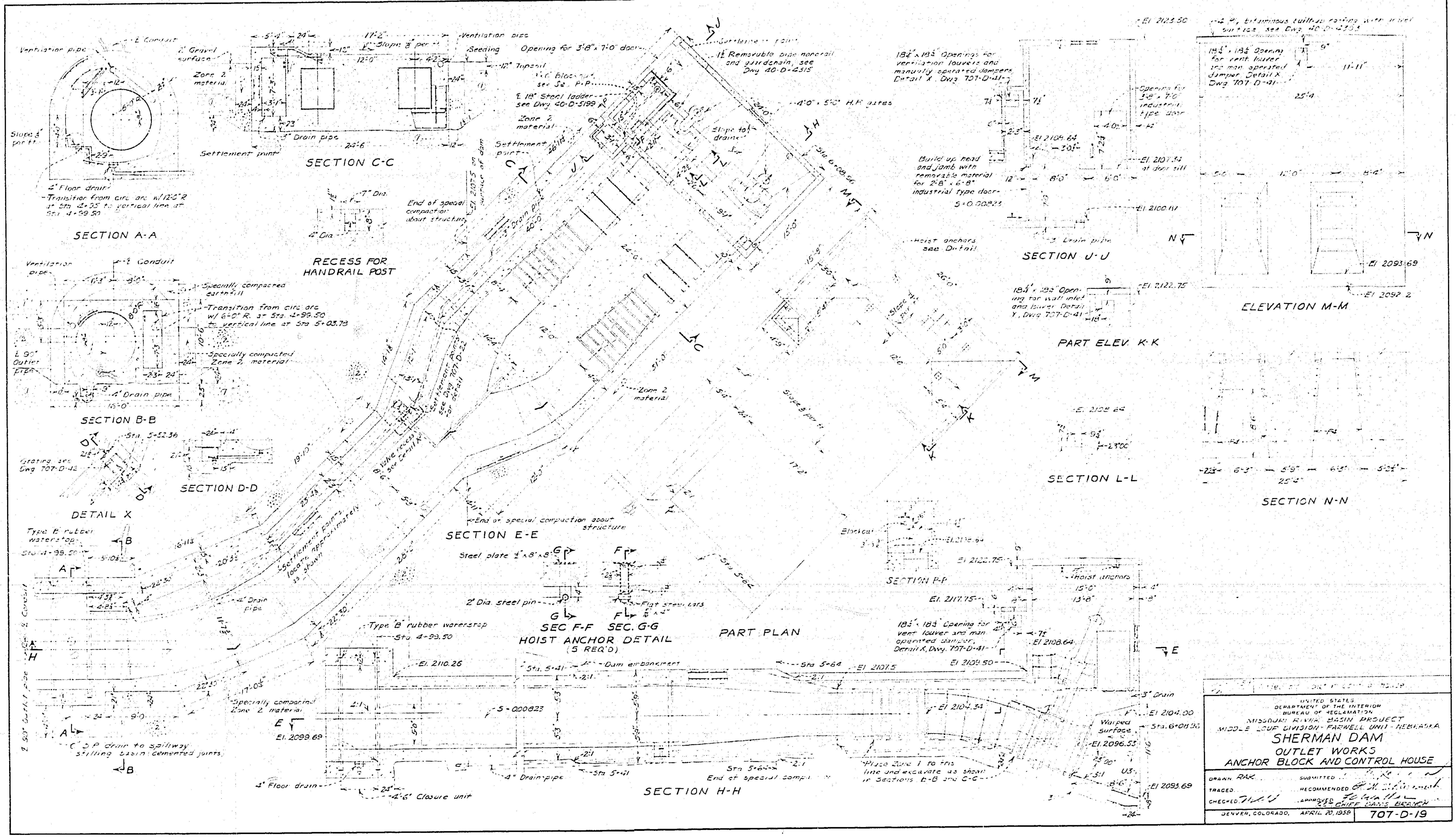
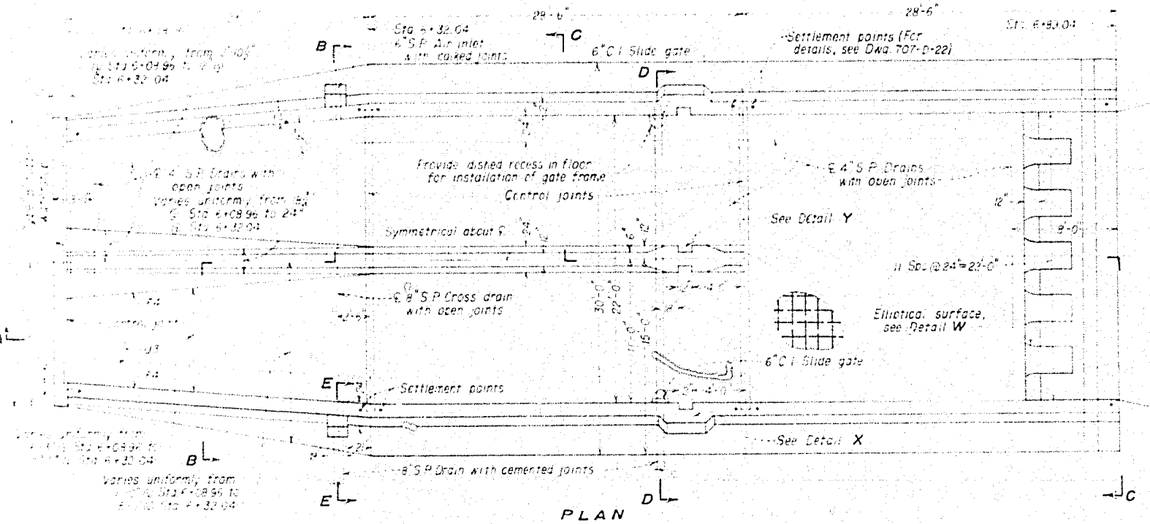
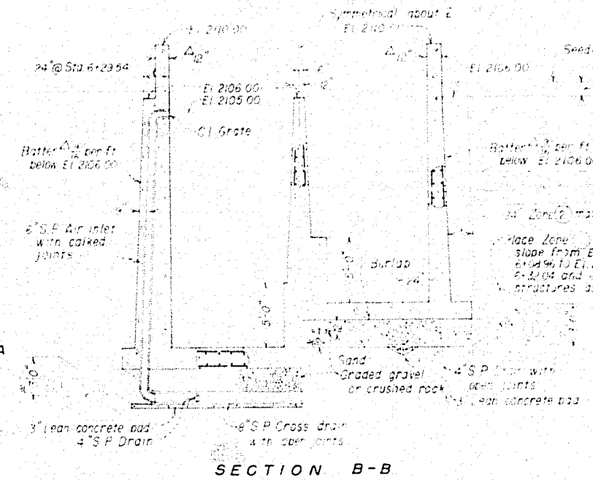
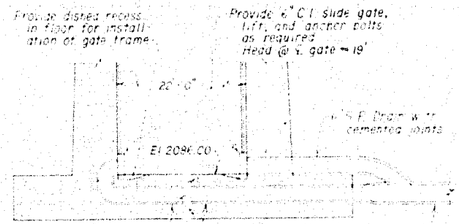


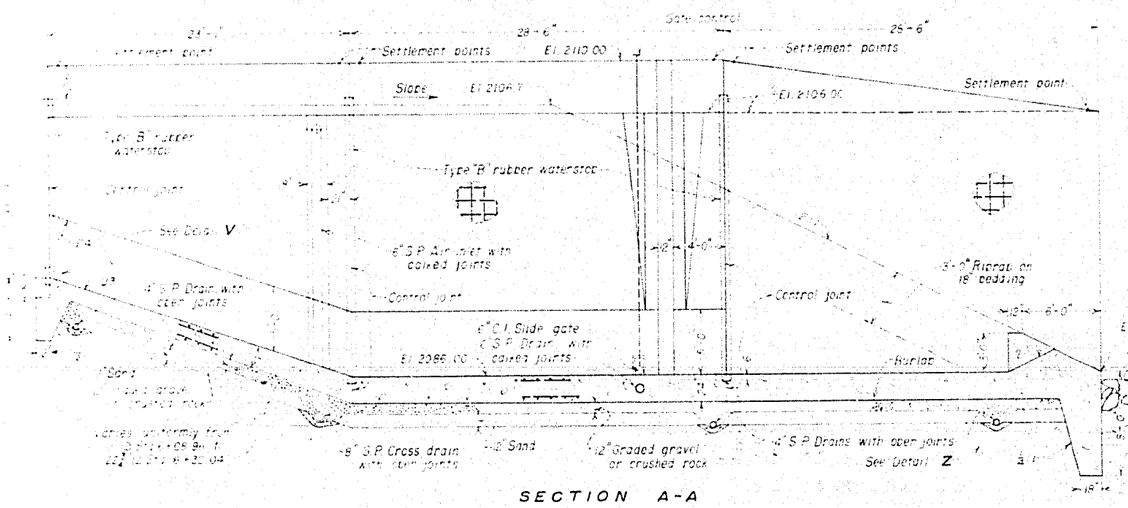
FIGURE 4
REPORT HYD. 455

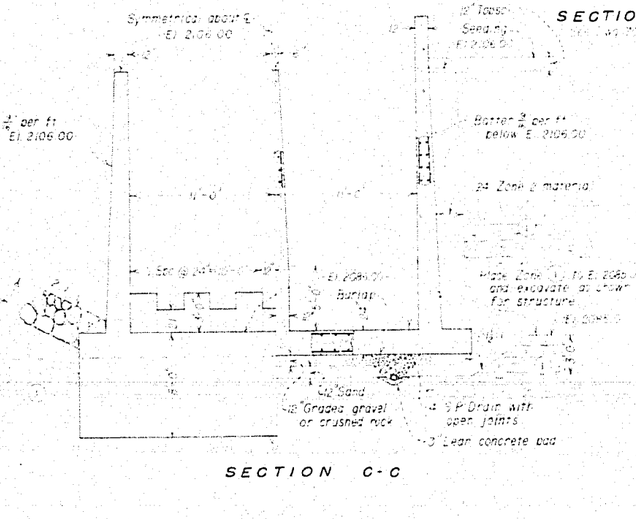










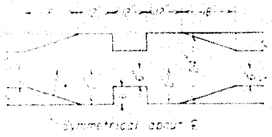


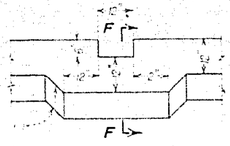
NOTES

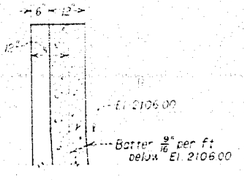
Indicates direction measured normal to excavated surface.
Indicates direction measured normal to face of wall.
Finish of walls 3 feet vertically above floor from Sta 4+08.96 to Sta 6+16.00
Finish of floor from Sta 6+08.96 to Sta 6+16.00

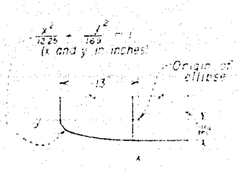
REFERENCE DRAWINGS

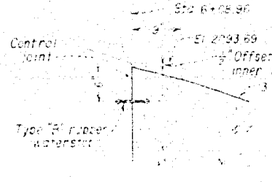
OUTLET WORKS STILLING BASIN REINFORCEMENT	707-D-51
SPILLWAY & OUTLET WORKS STRUCTURES GENERAL CONCRETE OUTLINE NOTES	707-D-5530











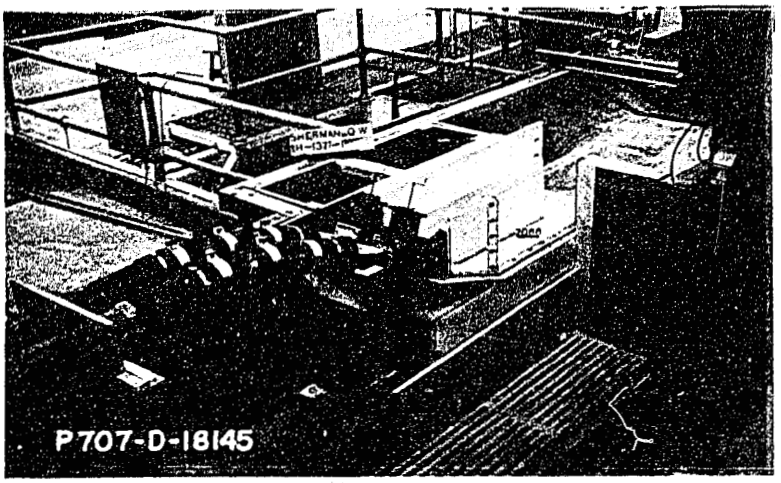
1-14-59	ADDED REFERENCE DRAWING		
9-5-57	TRACED		

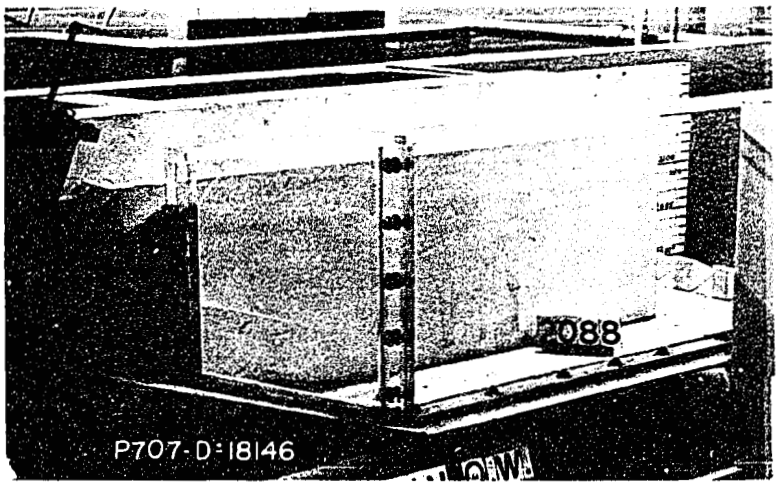
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
MIDDLE LOUP DIVISION-FARWELL UNIT-NEBRASKA

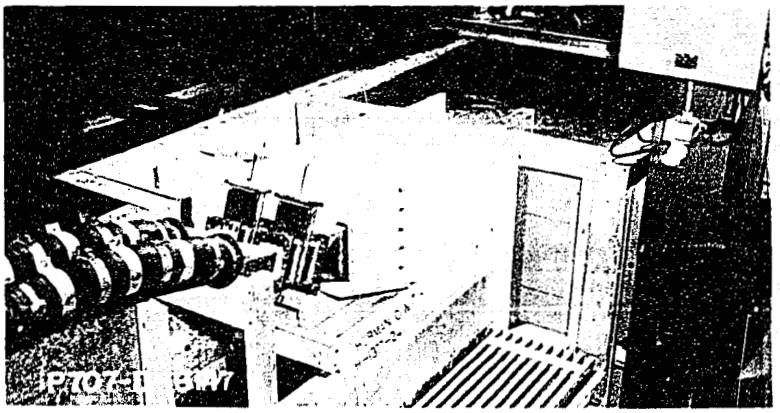
SHERMAN DAM
OUTLET WORKS
STILLING BASIN

DRAWN	M.H.	SUBMITTED	M. A. Jobard
TRACED	R.T.S.	RECOMMENDED	E. M. Whitehurst
CHECKED	M.G.P.	APPROVED	E. C. Holmes, Asst. Chief, Dams Branch

DENVER, COLORADO, APRIL 20, 1938 — 707-D-20

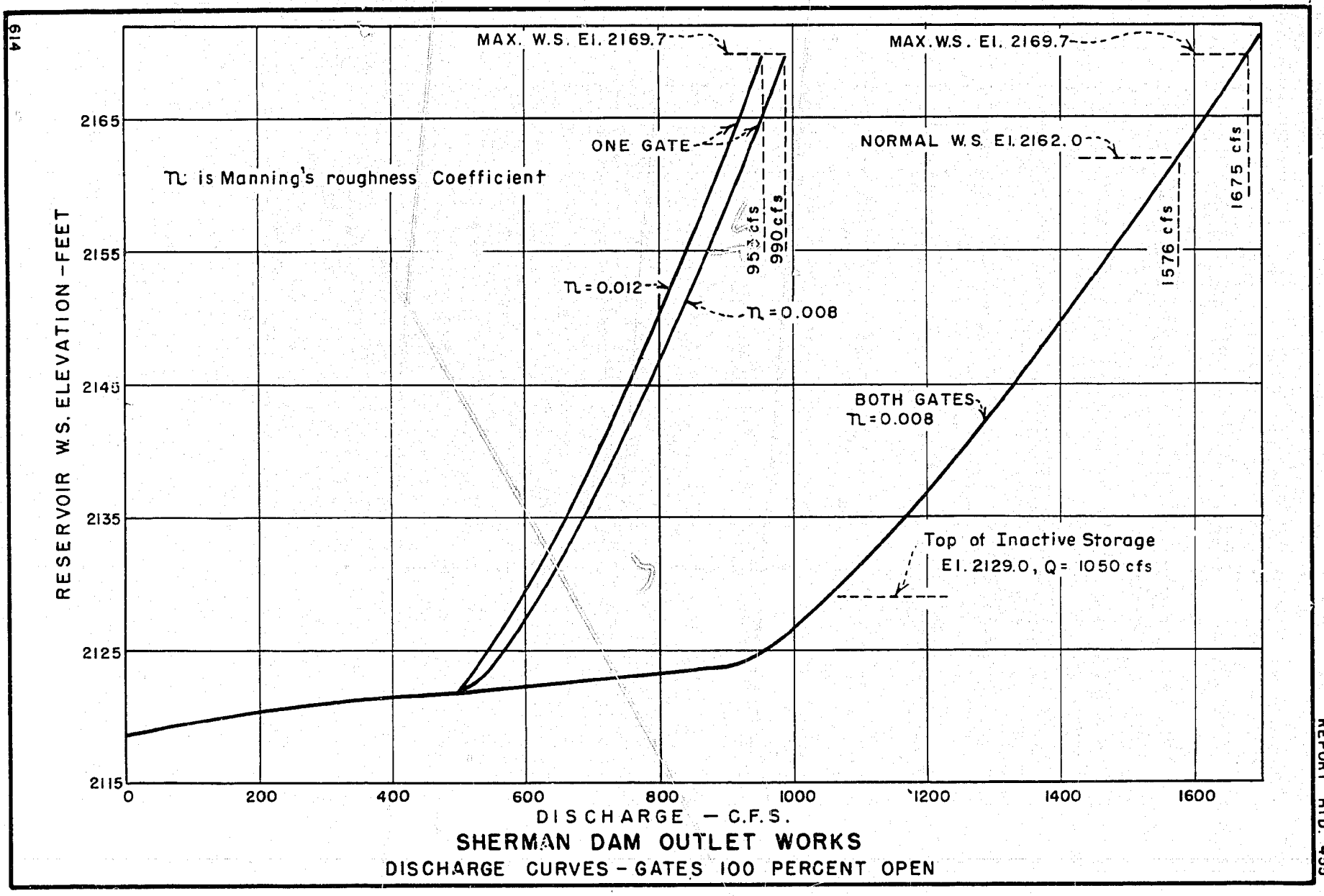






SHERMAN DAM OUTLET WORKS

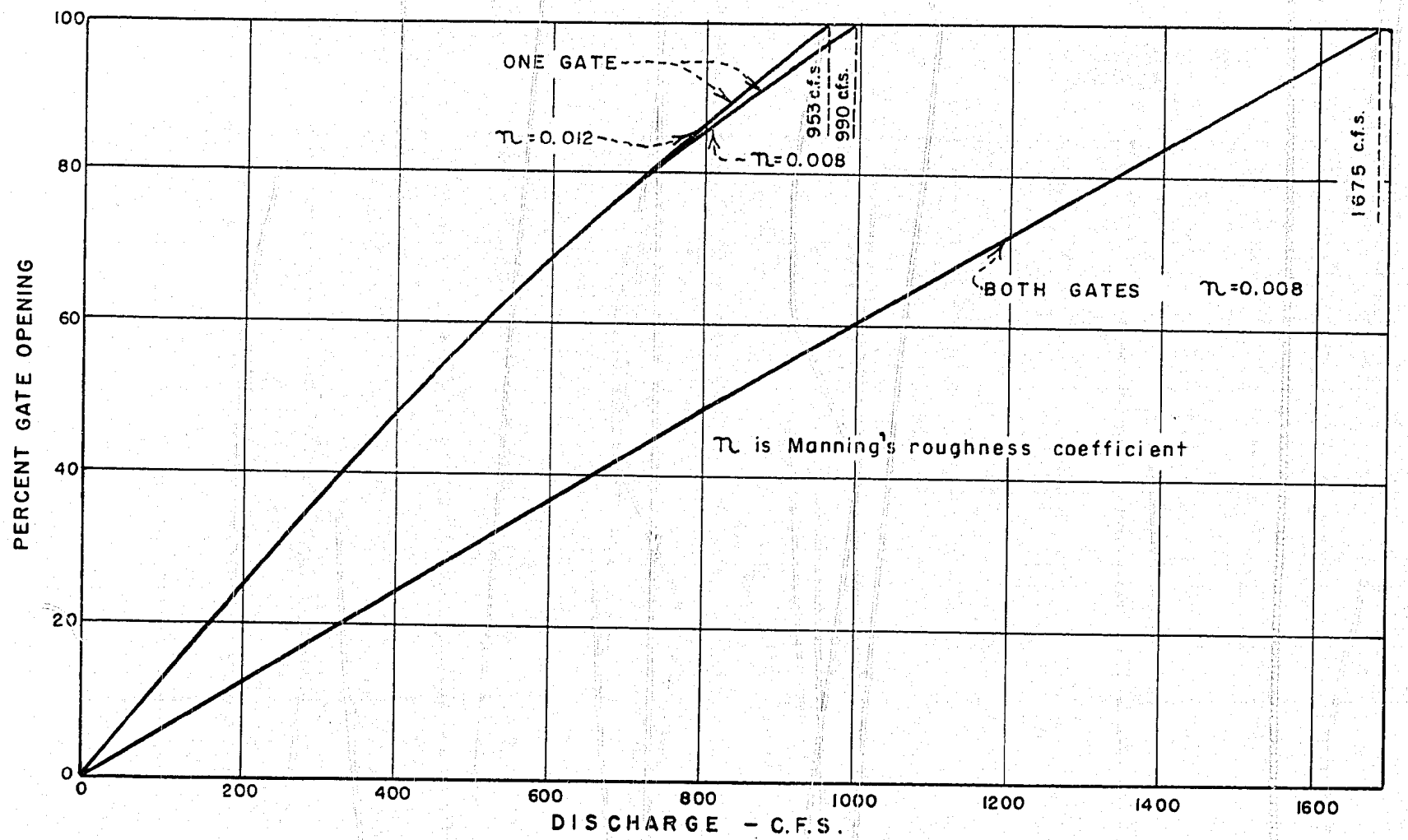
The 1:20 Scale Model of Preliminary Design.



SHERMAN DAM OUTLET WORKS

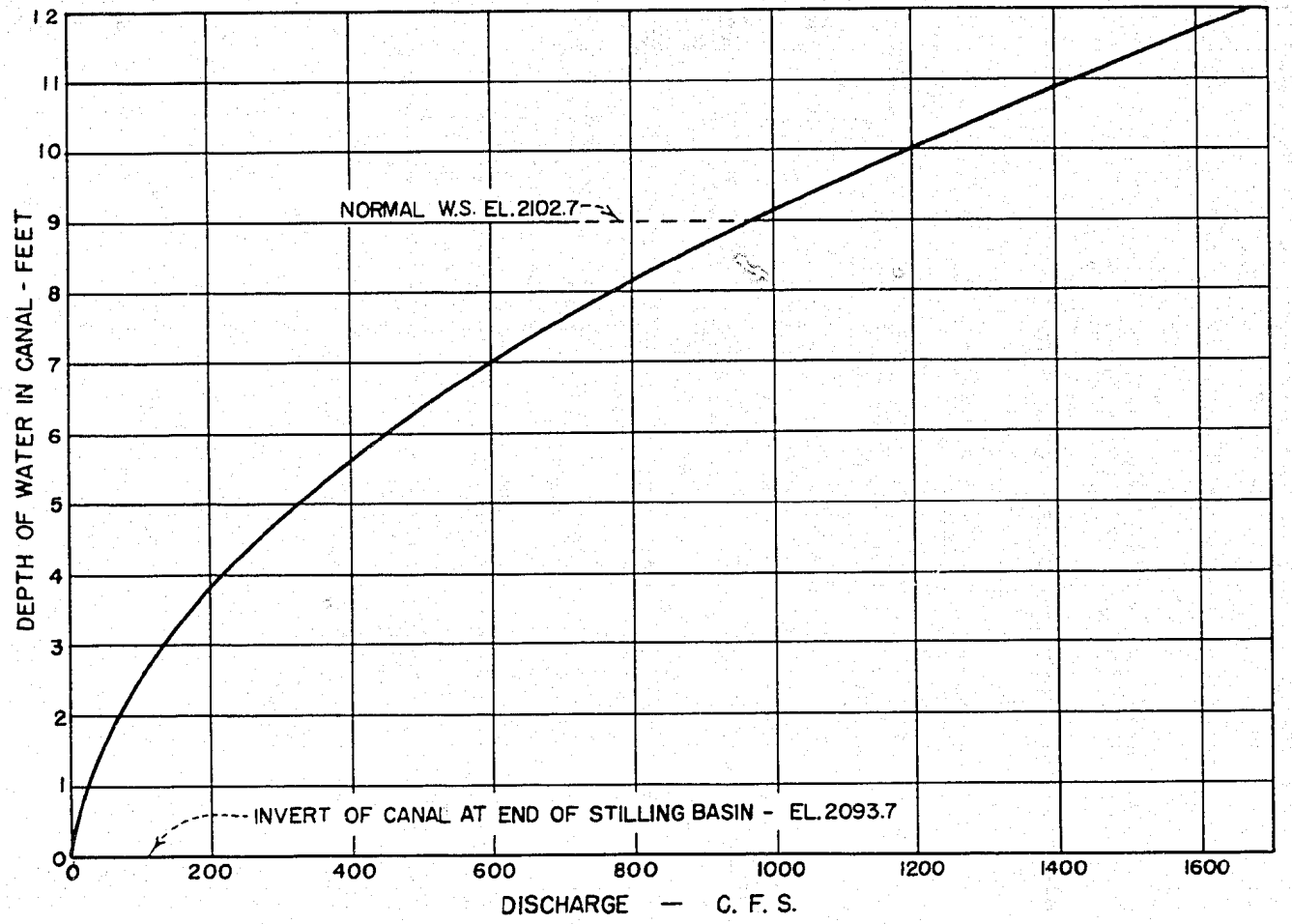
DISCHARGE CURVES - GATES 100 PERCENT OPEN

FIGURE 7
REPORT HYD. 455



SHERMAN DAM OUTLET WORKS
DISCHARGE CURVES - MAXIMUM WATER SURFACE ELEVATION 2169.7

FIGURE 8
REPORT HYD. 455

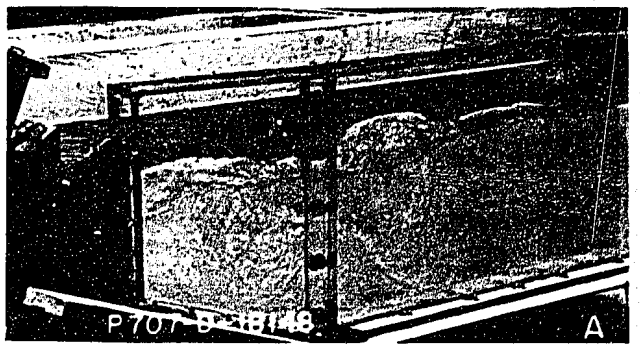


SHERMAN DAM OUTLET WORKS

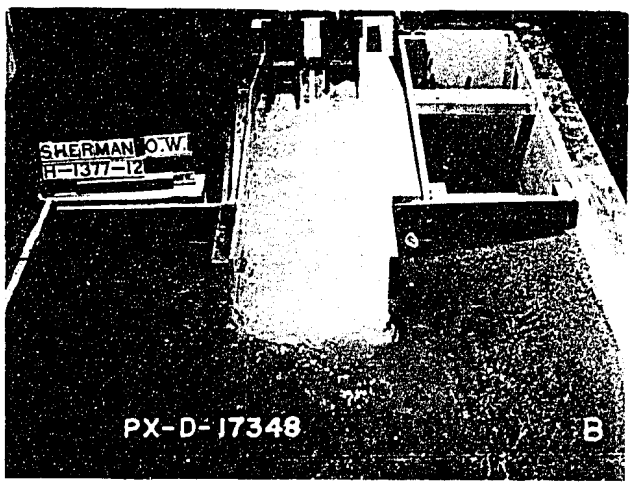
TAILWATER CURVE

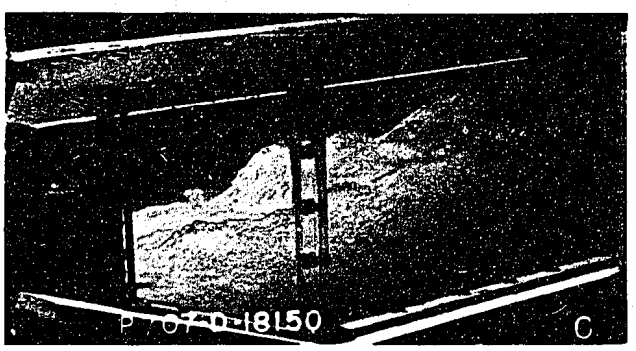
FIGURE 9
REPORT HYD. 455

Figure 10
Report Hyd. 455

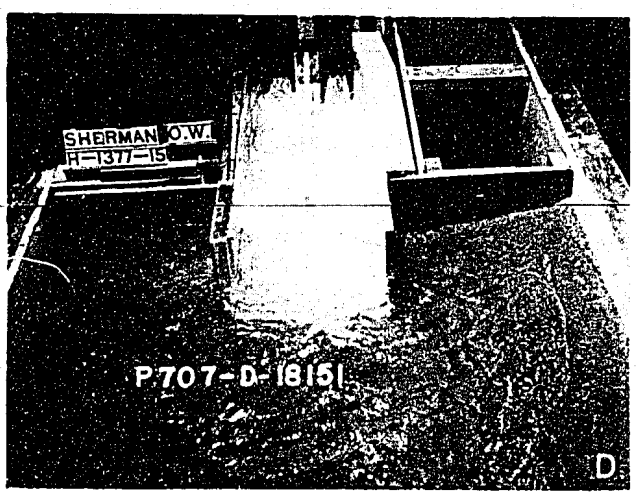


A and B. Two gates 100% open.



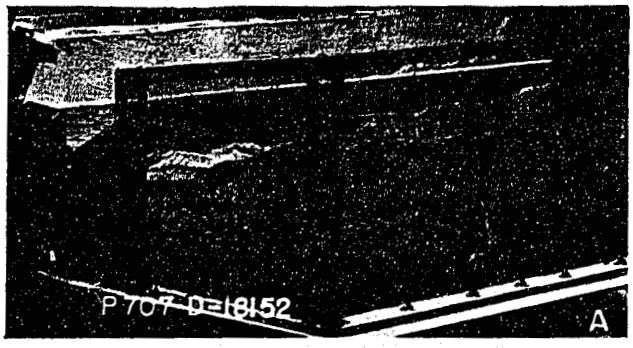


C and D. Two gates 60% open--
Maximum head.

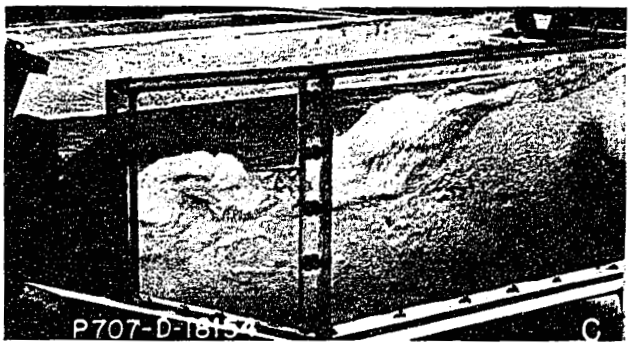


SHERMAN DAM OUTLET WORKS
Flow Conditions for Preliminary Design--960 c.f.s.
1:20 Scale Model

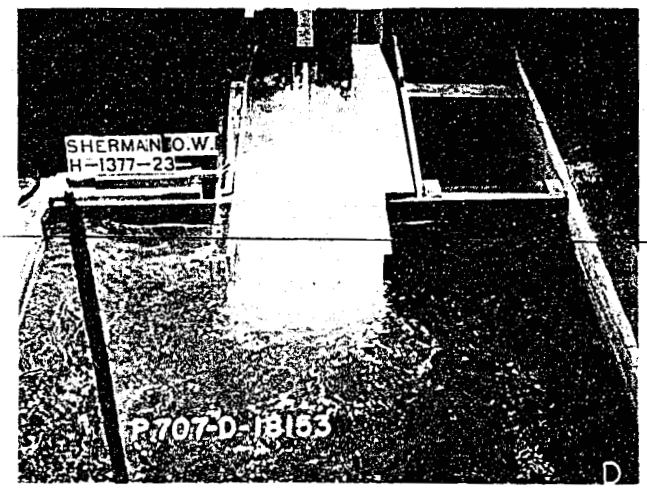
Figure 11
Report Hyd. 455



A and B. Without wave suppressor--
Two gates 100% open--Approximately maximum head.

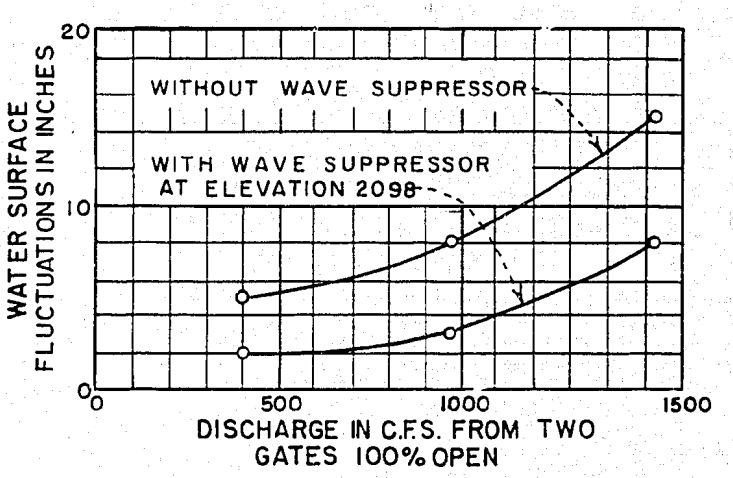


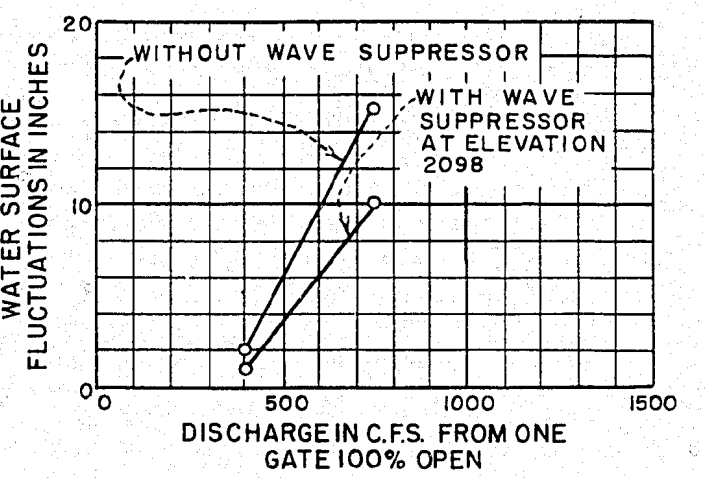
C and D. With wave suppressor--
Two gates 100% open--Approximately maximum head.

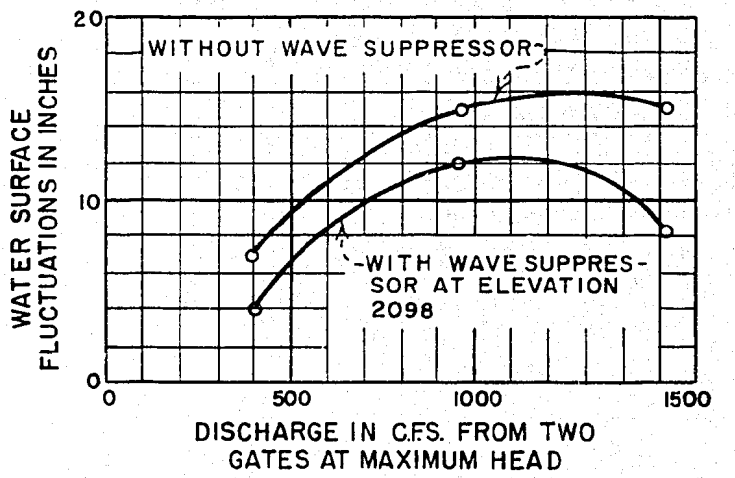


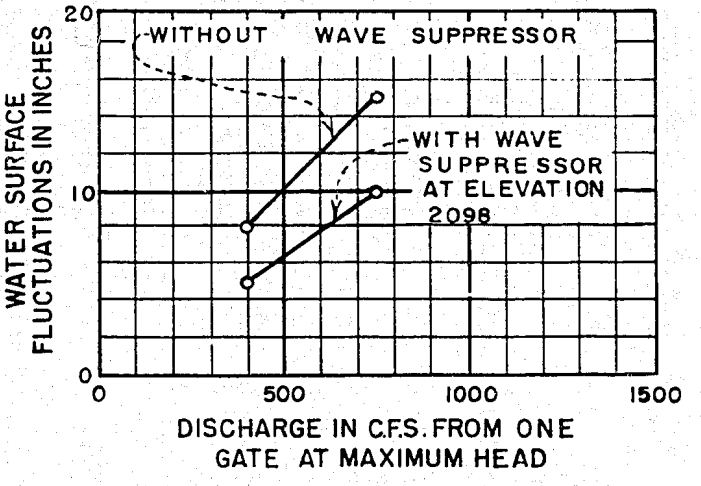
Note: Bottom of wave suppressor is at elevation 2098.

SHERMAN DAM OUTLET WORKS
Flow Conditions for Preliminary Design With and Without Wave Suppressor--
1,515 c.f.s.
1:20 Scale Model









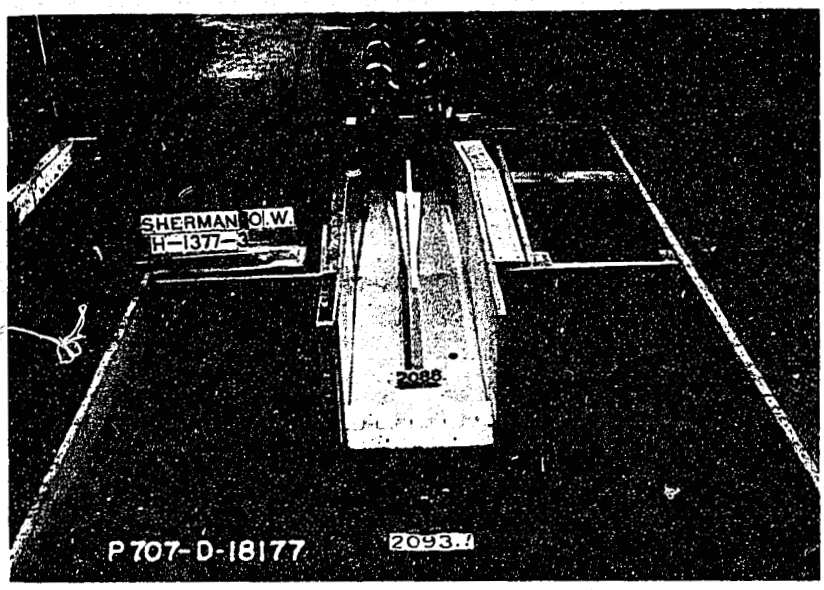
Water surface fluctuations were measured on the canal bank about 60 feet downstream from basin

SHERMAN DAM OUTLET WORKS

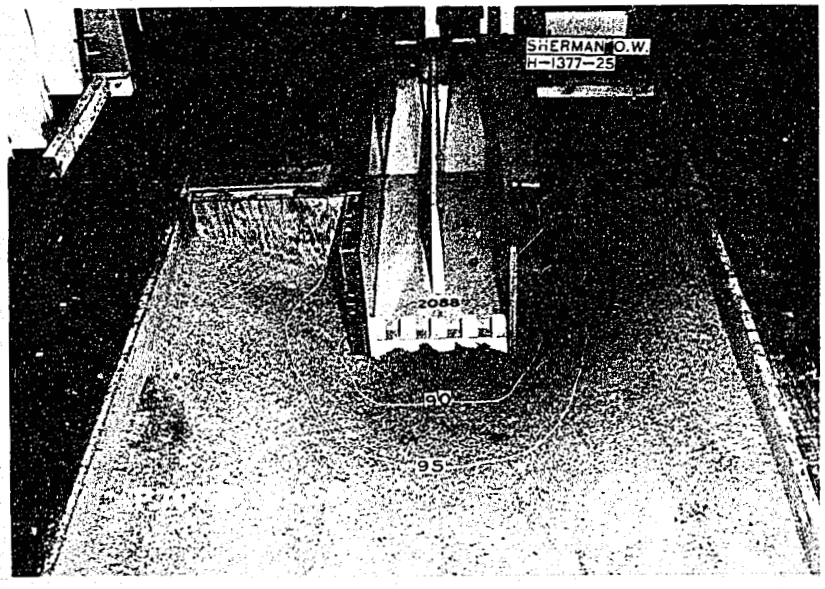
WATER SURFACE FLUCTUATIONS - PRELIMINARY DESIGN

1:20 SCALE MODEL

FIGURE 12
REPORT HYD. 455

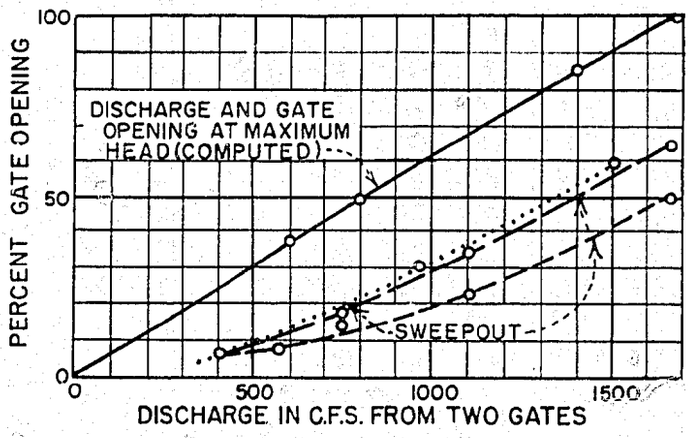


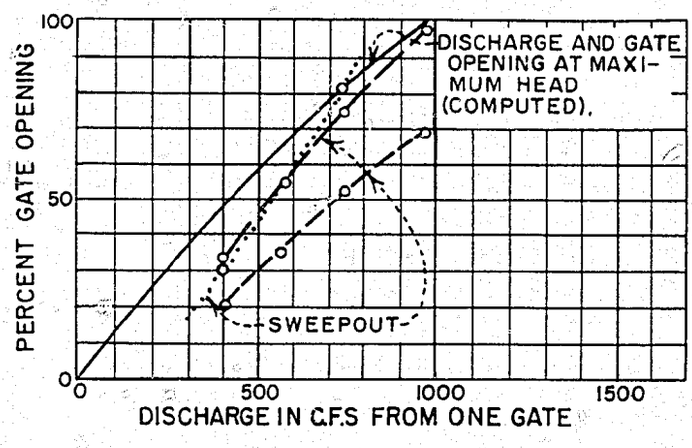
A. Bed molded for erosion test.



B. Erosion pattern after 2 hours model operation using both gates discharging 400 to 1,515 c.f.s.

SHERMAN DAM OUTLET WORKS
EROSION TEST
1:20 Scale Model





Note: Sweepout is considered to occur when the toe of the jump moves downstream to the end of center dividing wall. Sweepout data points which lie below the discharge curve show that head must be greater than the computed head to cause sweepout.

The data applies with or without wave suppressor. Maximum head occurs at reservoir elevation 2169.7

·····Preliminary Design

— — —Center wall shortened

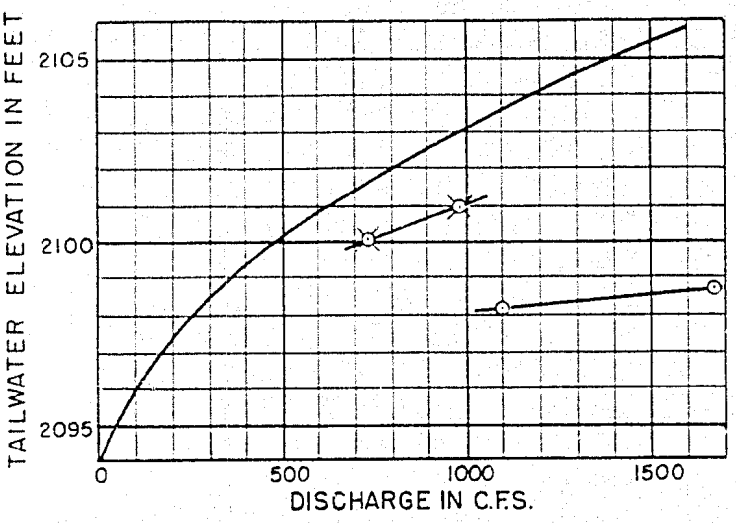
— — — —Center wall shortened and apron lowered 2 feet-Recommended Design

SHERMAN DAM OUTLET WORKS

SWEEPOUT OF HYDRULIC JUMP BY INCREASING HEAD

1:20 SCALE MODEL

FIGURE 15
REPORT HYD. 455



⊗ Sweepout for one gate, maximum reservoir elevation
o Sweepout for two gates, maximum reservoir elevation

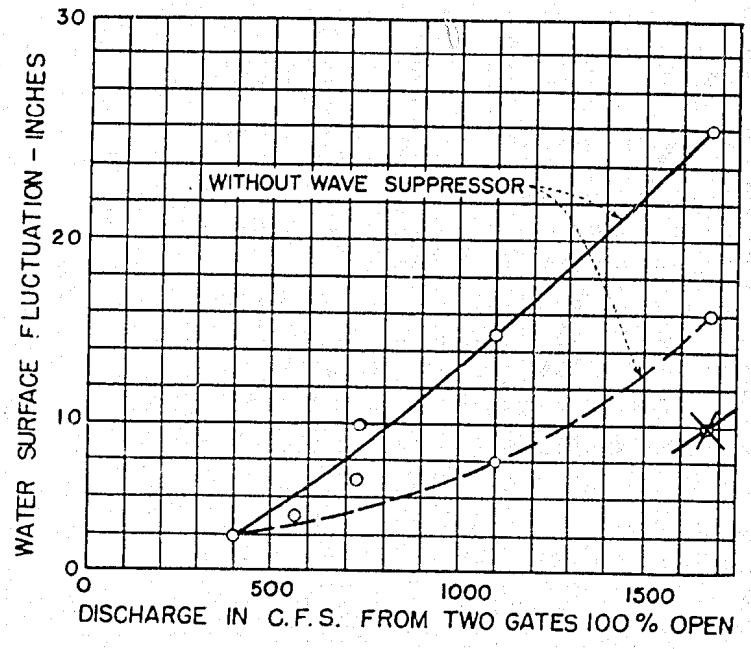
Note: Sweepout is considered to occur when the toe of the jump moves downstream to the end of the center dividing wall.
The elevation of the channel bed prevents sweepout of discharges less than shown by the curves.

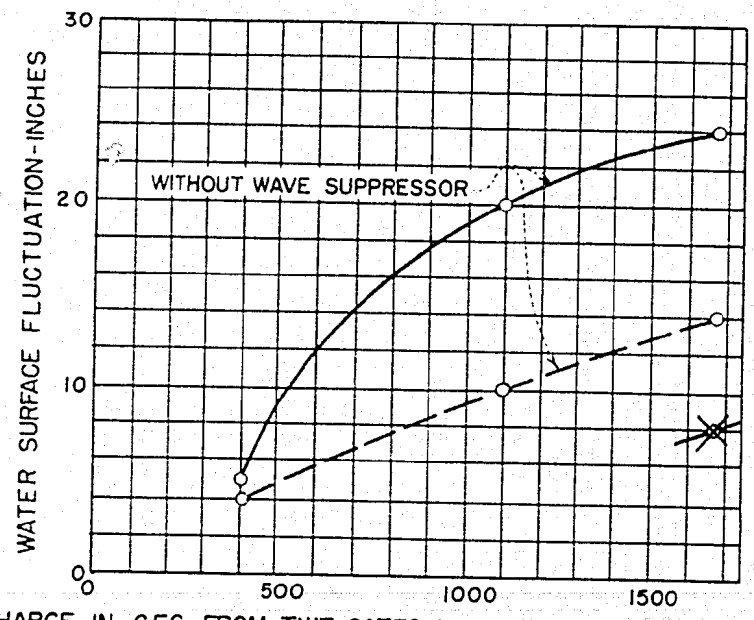
SHERMAN DAM OUTLET WORKS

SWEEPOUT OF HYDRAULIC JUMP BY LOWERING TAILWATER

RECOMMENDED DESIGN

1:20 SCALE MODEL





NOTE:
Water surface fluctuations were measured in the canal about 60ft. downstream from basin.

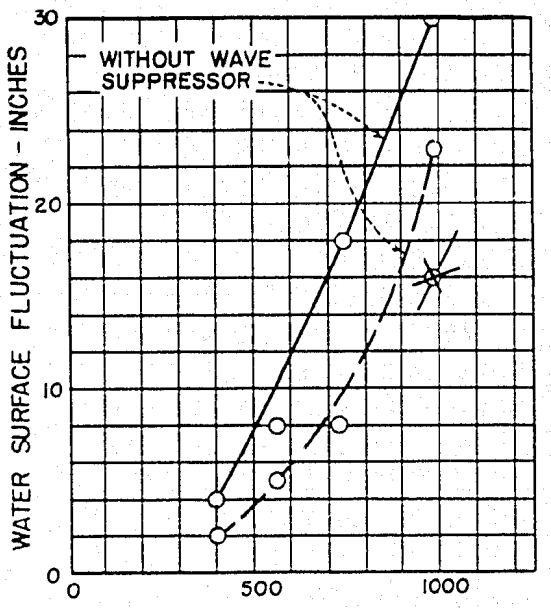
—— Center wall shortened.
– – Center wall shortened and apron lowered 2'-0" Recommended design.
—✕— Center wall shortened, apron lowered 2'-0" and wave suppressor at Elev. 2098.

SHERMAN DAM OUTLET WORKS

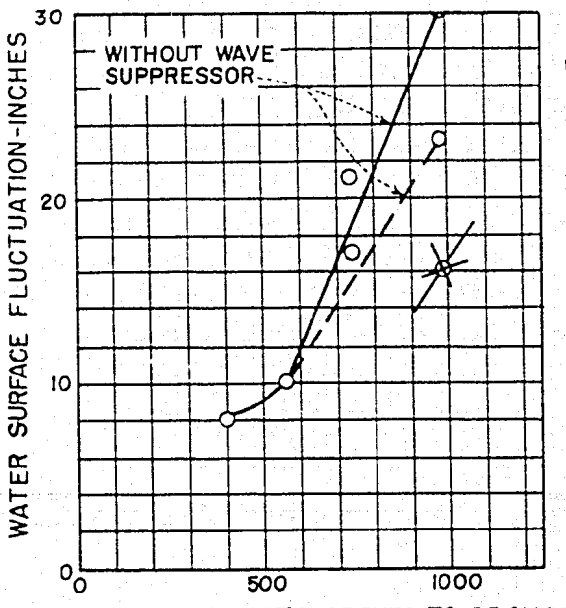
WATER SURFACE FLUCTUATIONS IN CANAL FOR TWO GATE OPERATION

1:20 SCALE MODEL

FIGURE 17
REPORT HYD. 455



DISCHARGE IN C F S FROM ONE GATE 100% OPEN



NOTE:
Water surface fluctuations were measured in the canal bank about 60ft. downstream from basin.

DISCHARGE IN CFS FROM ONE GATE OPENED TO PROVIDE MAXIMUM HEAD

—— Center wall shortened.
— — Center wall shortened and apron lowered 2'-0" Recommended design.
—⊗— Center wall shortened, apron lowered 2'-0" and wave suppressor at Elev. 2098

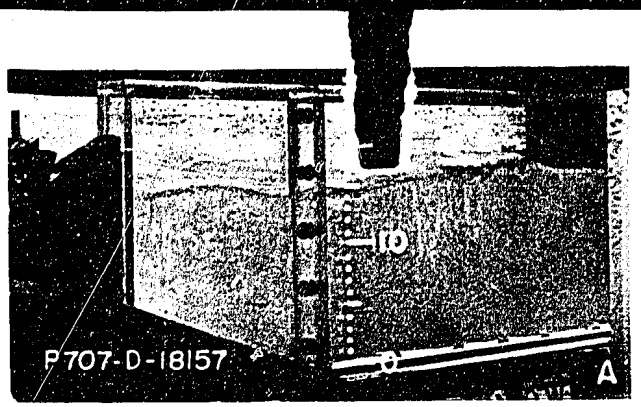
SHERMAN DAM OUTLET WORKS

WATER SURFACE FLUCTUATIONS IN CANAL FOR ONE GATE OPERATION

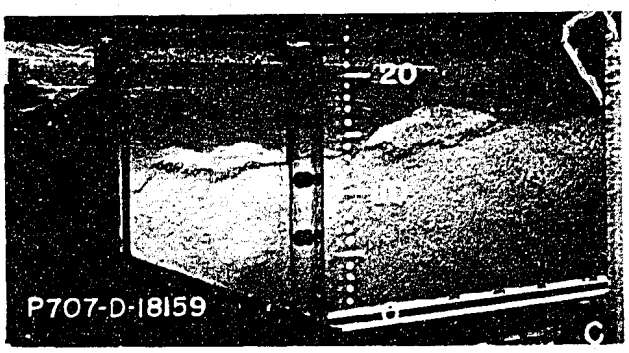
1:20 SCALE MODEL

614

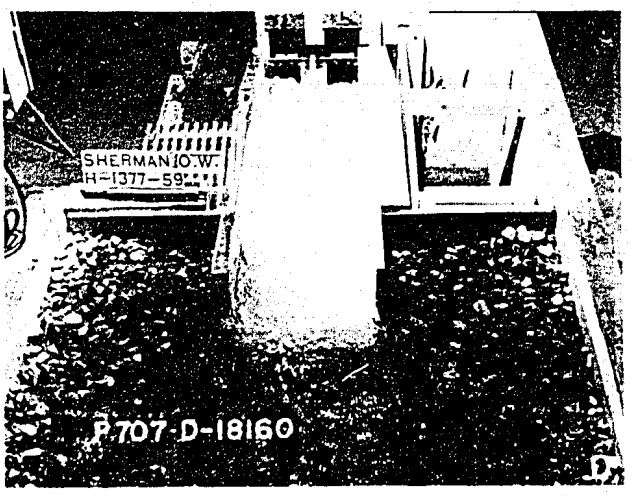
Figure 18
Report Hyd. 455



A and B. Two gates 100% open.



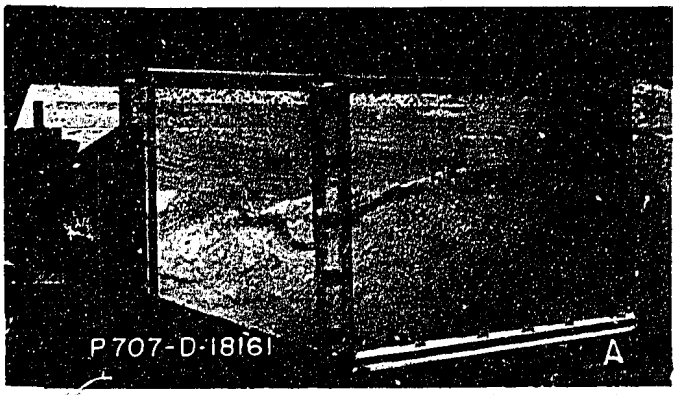
C and D. Two gates 60% open--
Maximum head.



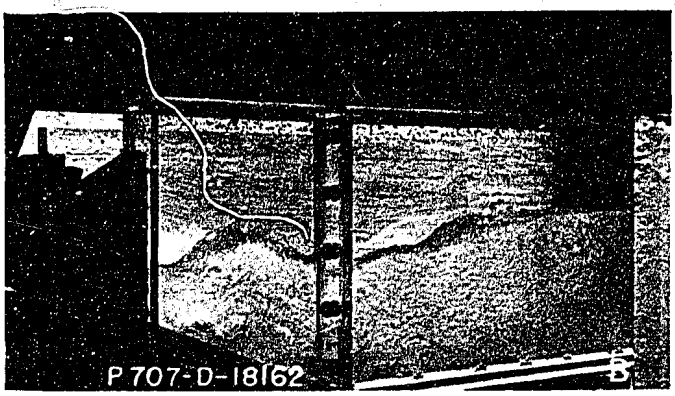
Note: The depth scale is in prototype feet. Zero is at basin floor elevation 2098

SHERMAN DAM OUTLET WORKS
Flow Conditions for Recommended Design--960 c.f.s.
1:20 Scale Model

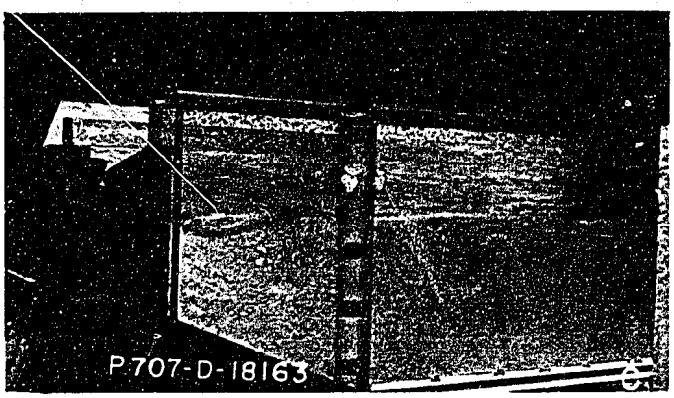
Figure 19
Report Hyd. 455



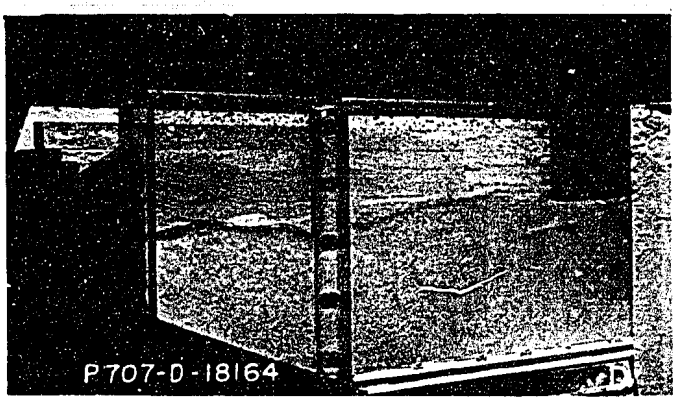
A. One gate 100% open.



B. One gate 65% open--
Maximum head.

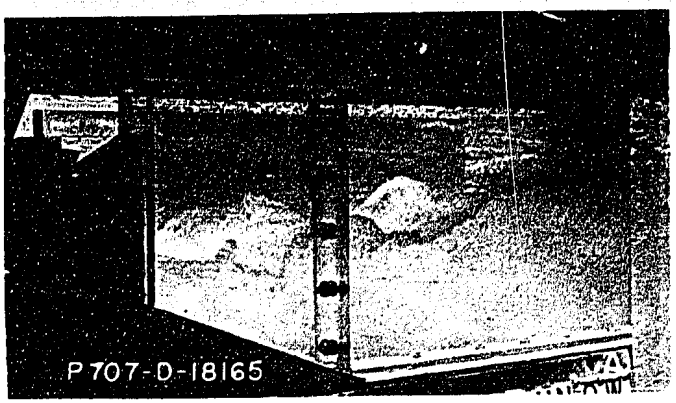


C. Two gates 100% open.

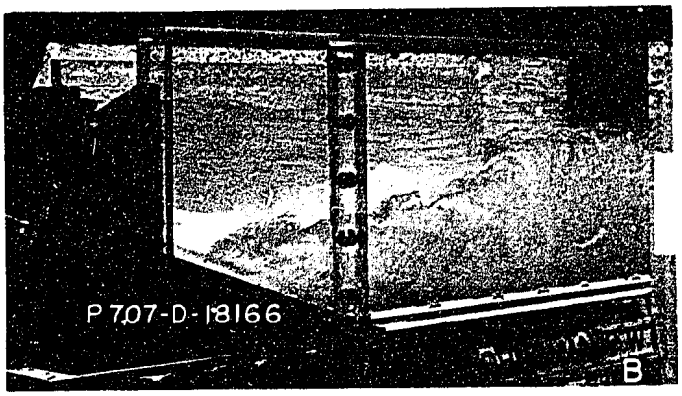


D. Two gates 35% open--
Maximum head.

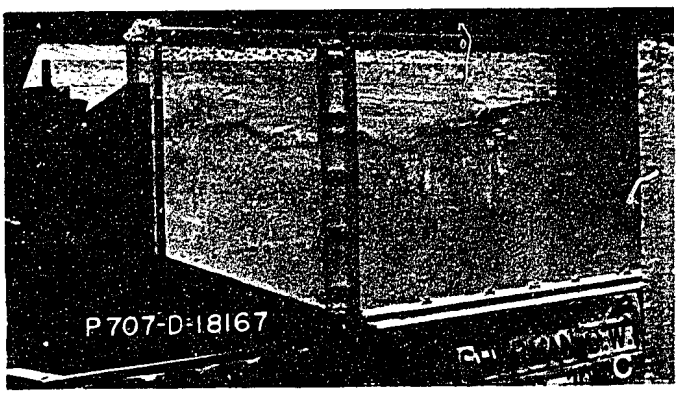
SHERMAN DAM OUTLET WORKS
Flow Conditions for Recommended Design--560 c.f.s.
1:20 Scale Model



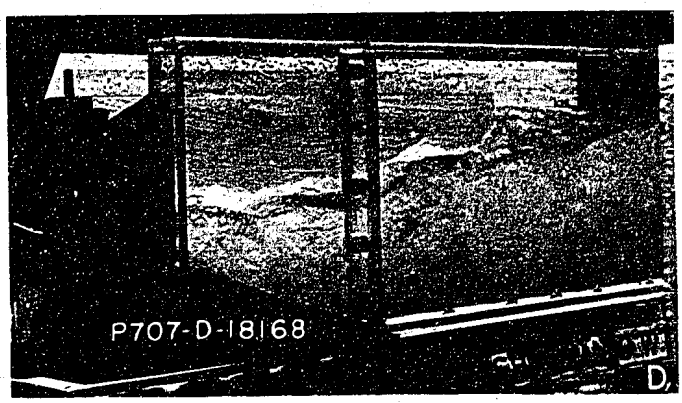
A. 735 c.f.s.--One gate 100% open.



B. 735 c.f.s.--One gate 80% open--Maximum head.



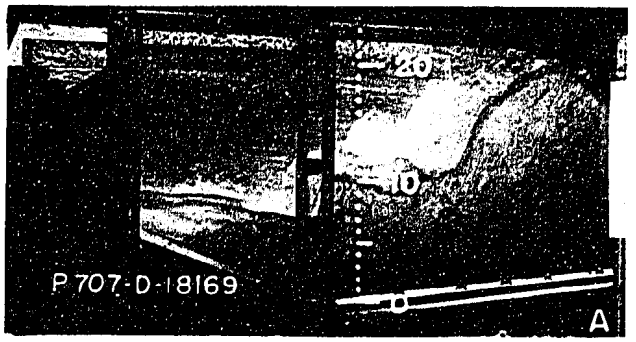
C. 1,100 c.f.s.--Two gates 100% open.



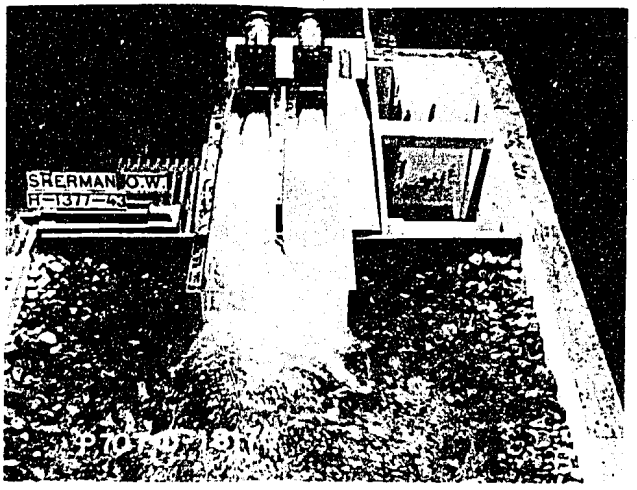
D. 1,100 c.f.s.--Two gates 65% open--Maximum head.

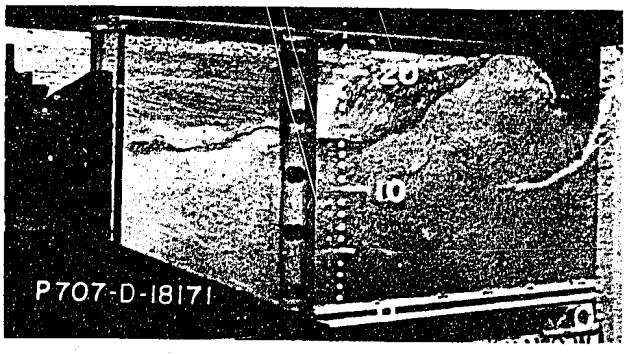
SHERMAN DAM OUTLET WORKS
Flow Conditions for Recommended Design--735 and 1,100 c.f.s.
1:20 Scale Model

Figure 21
Report Hyd. 455

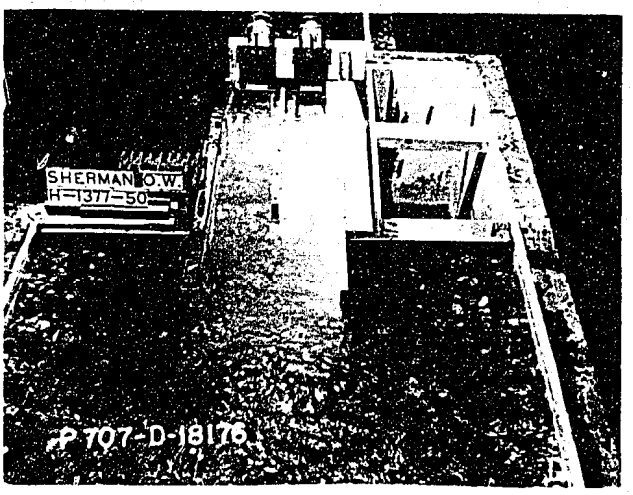


A and B. 990 c.f.s.--One gate 100% open.





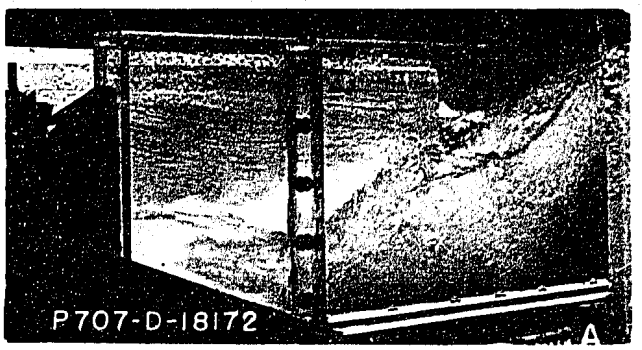
C and D. 1,675 c.f.s.--Two gates 100% open.



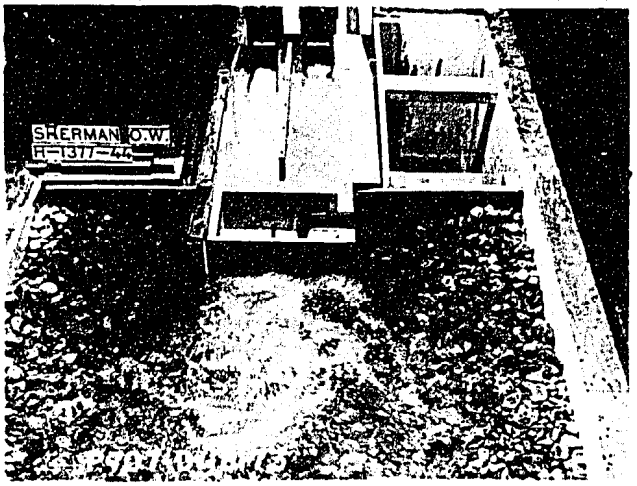
Note: The depth scale is in prototype feet. Zero is at basin floor elevation 2086.

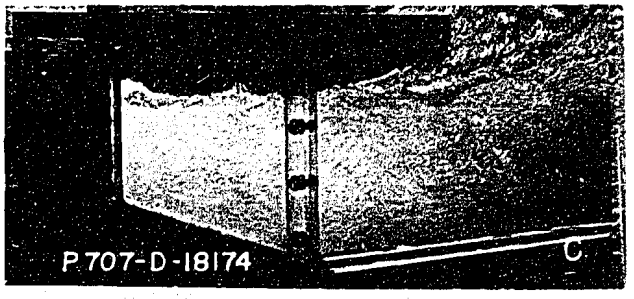
SHERMAN DAM OUTLET WORKS
Flow Conditions for Recommended Design--990 and 1,675 c.f.s.--Maximum Head
1:20 Scale Model

Figure 22
Report Hyd. 455

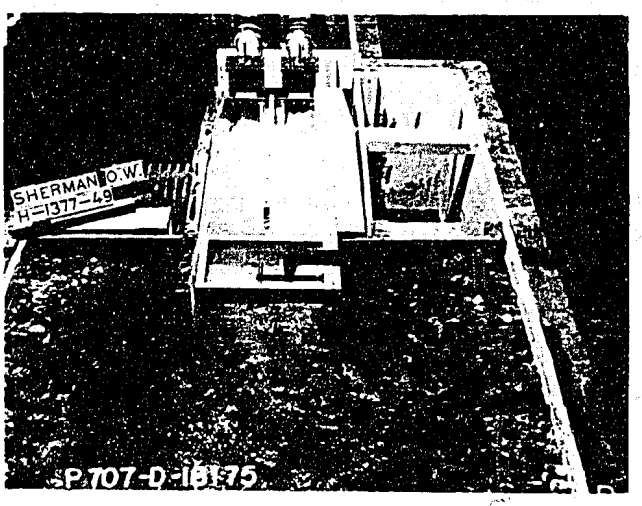


A and B. One gate 100% open--
Maximum Head--990 c.f.s.





C and D. One gate 100% open--
Maximum head--1,675 c.f.s.



Note: Bottom of wave suppressor is at elevation 2098.

SHERMAN DAM OUTLET WORKS
Flow Conditions With Wave Suppressor Added to Recommended Design--990 and 1,675 c.f.s.
1:20 Scale Model