UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF ARBUCKLE DAM OUTLET WORKS ARBUCKLE PROJECT, OKLAHOMA

Report No. Hyd-528

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

August 7, 1964

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ABSTRACT

Studies of a 1:18 scale model were made primarily to determine possible effects of operation of the outlet works on flow conditions in the downstream channel when the neighboring spillway is not operating. Also, operating characteristics of the outlet works stilling basin were observed and recorded. Conclusions of the study were: (1) Operation of the outlet works had no serious effects on flow conditions in the downstream channel. (2) The outlet works stilling basin performed satisfactorily for the test discharges. (3) Erosion in the simulated channel was moderate and the model indicated that the prototype riprap would give adequate protection against scour. (4) Pressures along the walls of the stilling basin were within safe limits of operation. (5) Water surface profiles indicated adequate freeboard against overtopping of the basin walls. (6) Waves in the downstream channel were 1 foot or less in height. (7) For the maximum outlet works discharge a safety margin of 2.7 feet was measured between the tailwater elevation with degraded channel and the tailwater elevation at which the hydraulic jump moves downstream and initially exposes the chute blocks.

DESCRIPTORS--*outlet works/*model tests/*stilling basins/ hydraulic jumps/hydraulics/hydraulic structures/scour/riprap/ eddies/wave action/water pressures/piezometers/pressure measuring equipment/recording systems/water surface profiles/ hydraulic models/ spillways/ backwater/ erosion/ negative pressures/ hydrostatic pressures/ discharge measurement/ freeboard/ safety factors/ operations

IDENTIFIERS--Arbuckle Project, Oklahoma/ Arbuckle Dam

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Office of Chief Engineer
Division of Research
Hydraulics Branch
Denver, Colorado
August 7, 1964

Report No. Hyd-528
Author: D. L. King
Checked by: T. J. Rhone
Reviewed by: W. E. Wagner
Submitted by: H. M. Martin

HYDRAULIC MODEL STUDIES OF ARBUCKLE DAM OUTLET WORKS--ARBUCKLE PROJECT, OKLAHOMA

PURPOSE

The primary purpose of these studies was to determine possible effects of operation of the outlet works on flow conditions in the downstream channel when the neighboring spillway is not operating. In addition, operating characteristics of the outlet works stilling basin were observed and recorded.

CONCLUSIONS

1. Operation of the outlet works had no serious effects on flow conditions in the downstream channel. Eddy currents were weak and caused no damage to the slopes of the channel. Some fine material was deposited in the spillway basin, Figure 6, which was believed to consist of suspended particles which settled to the bottom of the spillway basin pool.

2. The outlet works stilling basin performed satisfactorily for a discharge of 2,340 cfs (cubic feet per second), Figure 7 (spillway not operating), and a maximum discharge of 2,665 cfs, Figure 8 (during which the prototype spillway would also operate), for both initial and degraded channel conditions.

3. Sand erosion tests indicated that after 3 hours model operation (equivalent of 12 hours in the prototype) at a discharge of 2,340 cfs, tailwater for degraded channel, about 2 feet of erosion occurred at the right corner of the outlet works basin end sill and about 0.5 foot at the left corner of the spillway basin end sill, Figure 9(a). For a discharge of 2,665 cfs, degraded channel, about 3 feet of erosion occurred at the right corner of the outlet works basin end sill, Figure 9(b). Erosion was negligible at the left corner of the outlet works basin. Coarse material was also deposited on the downstream side of the spillway stilling basin end sill, Figure 6. A 3-hour riprap test at a discharge of 2,665 cfs, degraded channel, Figure 10, showed that the prototype riprap would give adequate

protection against bottom erosion and deposition of material on the spillway basin end sill. Wave action pulled some material from beneath the riprap at the top of the slopes which was deposited farther down the slopes.

4. Water manometer pressures along the right wall of the stilling basin, Figure 11, exhibited no high impact forces or excessively subatmospheric pressures. However, a record of instantaneous pressures showed very large pressure fluctuations in the turbulent region near the toe of the hydraulic jump.

5. Water surface profiles in the stilling basin, Figure 12, were similar to the pressure profiles and indicated adequate freeboard against overtopping of the basin walls.

6. Waves measured in the downstream channel at Station 11+92 were 9 inches high for a discharge of 2, 340 cfs and 13.5 inches high for 2, 665 cfs, with tailwater for either normal or degraded channel conditions, Table 2.

7. The model indicated a safety margin of 3.0 feet between the minimum tailwater (degraded channel) and the tailwater at which the chute blocks initially became exposed for the 2, 340 cfs discharge. A safety margin of 2.7 feet was determined for the 2, 665 cfs discharge, Table 3.

ACKNOWLEDGMENT

The model studies were accomplished through the cooperation of the Spillways and Outlet Works Section of the Dams Branch, Division of Design, and the Hydraulics Branch, Division of Research.

METRIC EQUIVALENTS

A summary of metric equivalents of important quantities used in this report is included as Table 1.

INTRODUCTION

Arbuckle Dam, the principal feature of the Arbuckle Project in southern Oklahoma, Figure 1, is 140 feet high and about 1, 900 feet long and contains approximately 2, 750, 000 cubic yards of fill material, Figure 2. The spillway and outlet works are the primary hydraulic features and are located in the right abutment of the dam. The intake structures are approximately 300 feet apart in the reservoir and the conduits converge at a 15° angle so that the centerlines of the stilling basins are only about 40 feet apart at the downstream ends of the basins. The convergence of the structures and the proximity of the stilling basins gave concern as to the possible effects of operation of one structure on the other.

The spillway consists of a drop inlet, a 9-foot 6-inch diameter circular conduit, a vertically curved chute, and a hydraulic jump stilling basin. Only the downstream portion of the 30-foot-wide basin was represented in the model. The uncontrolled spillway has a maximum discharge capacity of 3,410 cfs at reservoir elevation 914.2.

The outlet works, Figure 3, includes a drop inlet, a 7-foot 6-inch diameter circular conduit, followed by regulating gates, a 9-foot-wide flat bottom conduit, vertically curved chute, and a 20-foot-wide hydraulic jump stilling basin, Figure 4. Both basins discharge into a 100-foot-wide curved channel. The outlet works discharge is 2,340 cfs with the reservoir at the brink of the spillway crest or elevation 885.3; the maximum discharge is 2,665 cfs at reservoir elevation 914.2. Since the spillway is uncontrolled, the spillway also will be discharging when the reservoir elevation exceeds 885.3. Both stilling basins are USBR Type II, with chute blocks and dentated end sills.1/

THE MODEL

The 1:18 scale model included a portion of the flat-bottomed conduit of the outlet works, the vertically curved diverging chute, the hydraulic jump stilling basin, and approximately 250 feet of downstream channel. A nonoperating portion of the spillway stilling basin was also represented.

The chute and stilling basins were constructed of plywood with piezometers installed in the right wall of the outlet works stilling basin. Sand with an average size of about 0.8 mm (millimeter) was used to form the downstream channel, a portion of which was later covered with rock with a maximum size of about 2 inches to simulate riprap protection.

Water was supplied to the outlet works through a recirculating distribution system, with the flow rate measured by permanent volumetrically calibrated Venturi meters. Correct velocities in the chute

1/"Hydraulic Design of Stilling Basins and Energy Dissipators," Engineering Monograph No. 25, U.S. Department of the Interior, Bureau of Reclamation.

were maintained by adjusting a thin-leaf slide gate to give the proper relationship between discharge and pressure head in the conduit upstream from the gate. This relationship was determined by computing head losses occurring between the prototype reservoir and the pressure measuring section. The discharges were based on a Manning's "n" value of 0.008 for both concrete and steel.

Tailwater elevations were adjusted with a movable tailgate according to the tailwater curves in Figure 5. Water surface elevations were determined by a staff gage on one wall of the nonoperating spillway stilling basin, in which a relatively quiet water surface was maintained.

THE INVESTIGATION

The outlet works discharge of 2, 340 cfs occurs when the reservoir water surface is at the spillway crest, just before the spillway begins to operate. The effect of this outlet works discharge on flow conditions in the downstream channel was of primary concern, with special attention given to the possibility of material being swept into and deposited in the nonoperating spillway basin. Such deposited material could cause abrasion of the concrete surfaces during subsequent operation of the spillway. Data were also taken for an outlet works discharge of 2, 665 cfs, during which the maximum spillway discharge would also occur. However, since the model spillway stilling basin was inoperable, conditions in the model channel downstream from the basins were unrealistic. Data taken within the outlet works stilling basin for the 2, 665 cfs discharge were, however, truly representative. Performance was evaluated for both initial and degraded channel conditions.

The Preliminary Stilling Basin--(Recommended)

Effects of outlet works operation on the spillway stilling basin and the downstream channel.--The outlet works was operated at a discharge of 2, 340 cfs to determine the flow conditions in the downstream channel with particular regard to the possibility of riverbed material being swept into the nonoperating spillway stilling basin. The model showed that the outlet works flow was effectively directed in a downstream direction and no strong eddy currents existed along the banks of the channel. However, bottom currents resulted in some coarse material being swept against the downstream side of the dentated end still of the spillway stilling basin, Figure 6, after a period of operation equivalent to 12 prototype hours (about 3 hours model time). It should be noted that this test was made with sand forming the channel bed. Riprap tests, described later in this report, indicated that the rock protection eliminated this condition.

Some fine material was deposited in the spillway basin, Figure 6, during operation both with and without riprap protection. It was believed that this material consisted of suspended particles which settled in the quiet pool of the spillway basin. In this case, it would be incorrect to assume that this material represented a prototype size based on the model scale. It is likely that material deposited in the prototype basin would be of the same size as the model particles and would not result in abrasive damage during subsequent operation of the spillway. However, riprap should be carefully placed in the immediate vicinity of the end sills to insure against deposition of coarse material on the spillway basin end sill, as previously described.

Stilling basin operation.--The outlet works stilling basin performed satisfactorily for a discharge of 2,340 cfs (spillway not operating) and a maximum discharge of 2,665 cfs (during which the prototype spillway would also operate) for both initial and degraded channel conditions. For the 2,340 cfs discharge the difference between initial and degraded channel had little effect on the basin operation, Figure 7.

The turbulence of the hydraulic jump was confined to the stilling basin. Rapid expansion of the flow took place immediately beyond the end of the basin, resulting in an upstream surge into the spillway basin. This condition probably also existed along the bottom of the channel, which explains the deposition of material on the spillway basin end sill.

The maximum discharge of 2,665 cfs, Figure 8, represented the flow conditions only in the outlet works stilling basin. Since the spillway will be operating during this outlet works discharge flow conditions in the downstream channel, including eddies near the spillway stilling basin, were not truly represented in the model. Surging in the outlet works stilling basin was markedly stronger than that observed for the lesser discharge, and some turbulence prevailed beyond the end of the basin, especially during operation with the degraded tailwater condition. The upstream surge into the spillway basin was again noted, but would not exist during operation of the spillway.

Sand erosion and riprap tests.--The channel bed was initially shaped in sand with an average size of 0.8 mm and was reshaped after each test run. Each test was continued for about 3 hours model time, equivalent to 12 hours prototype time. The tests were conducted only with the degraded channel condition.

For a discharge of 2,340 cfs, erosion to a depth of about 2 feet occurred at the right corner (looking downstream) of the outlet works basin end sill and about 0.5 foot of erosion was noted at the left corner of the spillway basin end sill, Figure 9(a). The erosion was negligible at the left corner of the outlet works basin. For the 2,665 cfs discharge the scour pattern was very similar to that for the lesser discharge, with about 3 feet of erosion at the right corner of the outlet works basin, Figure 9(b). The asymmetry of the pattern is due to the deposition, in front of the left half of the basin, of material which was pulled down from the left channel slope. The amount of scour was not excessive and was confined to the area immediately downstream from the stilling basin. Wave action caused the beaching along the tops of the channel slopes, which is evident in the photographs.

Rock with maximum size pieces of about 2 inches was placed on the sand bed to simulate the 1/2- to 1-cubic-yard prototype riprap. The riprap was subjected to approximately 3 hours of model operation at a discharge of 2,665 cfs, degraded channel, to represent the most severe operating condition. Figure 10 shows that no apparent movement of the rock took place. However, sand was pulled from beneath the riprap by wave action and deposited lower on the slopes, which was probably the source of the fine material deposited in the spillway basin. This leaching action may or may not occur in the prototype, depending on the nature of the material beneath the riprap.

Pressures.--Piezometers were placed beneath the water surface of the hydraulic jump along the right training wall of the outlet works stilling basin, Figure 11. Water manometer readings exhibited no high impact pressures or severe subatmospheric pressures and no large fluctuations in pressure. Pressure profiles based on average water manometer pressures are also shown in Figure 11, along with the supporting data. Instantaneous pressures were recorded in the very turbulent region near the toe of the hydraulic jump using electronic pressure transducers connected to a direct writing oscillograph. Other model studies have indicated very large instantaneous fluctuations in pressure in this region, similar to those observed in this model. The pressures are listed in the table of Figure 11. The effect of these large pressure fluctuations is unknown and studies are continuing to determine their possible cause and effect. Average water manometer pressures agree quite closely with the average instantaneous pressures, which supports the accuracy of either method of measurement. Instantaneous pressures on the downstream portion of the training wall were not recorded because previous studies have shown them to be nearly identical to the water manometer pressures, which can be used to determine forces acting on the wall.

Water surface profiles.--Water surface profiles, measured for discharges of 2,340 and 2,665 cfs with both initial and degraded channel conditions are shown in Figure 12. The profiles show the maximum and minimum water surface, indicating the amount of surging in the basin. These profiles, when compared to Figure 11, show similarity with the pressure profiles, indicating essentially hydrostatic pressure distribution on the wall.

Waves.--Waves were measured at approximately Station 11+92 in the downstream channel as an additional means of evaluating the efficiency of the hydraulic jump stilling basin. Waves were relatively small, approximately 1 foot or less in height for all test conditions, Table 2.

Tailwater sweepout tests.--Tests were conducted to determine the margin of safety between the minimum tailwater elevation (degraded channel) and the tailwater elevation at which the toe of the jump moves downstream and initially exposes the chute blocks. This safety margin was found to be 3.0 feet for a discharge of 2,340 cfs, and 2.7 feet for the 2,665 cfs discharge when the spillway is operating at maximum flow, Table 3. It was difficult to determine the tailwater elevation at which the hydraulic jump completely swept from this basin, but other studies have indicated that complete sweepout will occur at a tailwater elevation 1 to 2 feet below the elevation at which the chute blocks become exposed.

Table 1

METRIC EQUIVALENTS OF IMPORTANT QUANTITIES USED IN THIS REPORT

Feature	English units	Metric units
Height of dam, riverbed to crest	140 ft	42.7 m
Length of dam	1,900 ft	579 m
Dam fill volume	2,750,000 cubic yards	2,103,000 cubic meters
Spillway discharge at maximum reservoir	3,410 cfs	96.5 cms
Maximum reservoir elevation	914.2 ft	278.6 m
Outlet works discharge at maximum reservoir	2,665 cfs	75.4 cms
Outlet works discharge with reservoir at spillway crest	2,340 cfs	66.2 cms
Spillway stilling basin width	30 ft	9.1 m
Outlet works stilling basin width	20 ft	6.1 m
Initial tailwater depth at end of basin for outlet works Q = 2,340 cfs	23.9 ft	7.3 m
Degraded tailwater depth for outlet works Q = 2,340 cfs	21.9 ft	6.7 m
Initial tailwater depth for outlet works Q = 2,665 cfs	26.1 ft	8.0 m
Degraded tailwater depth for outlet works Q = 2,665 cfs	24.1 ft	7.3 m

Table 2

WAVE HEIGHTS AT STATION 11+92 IN PROTOTYPE FEET

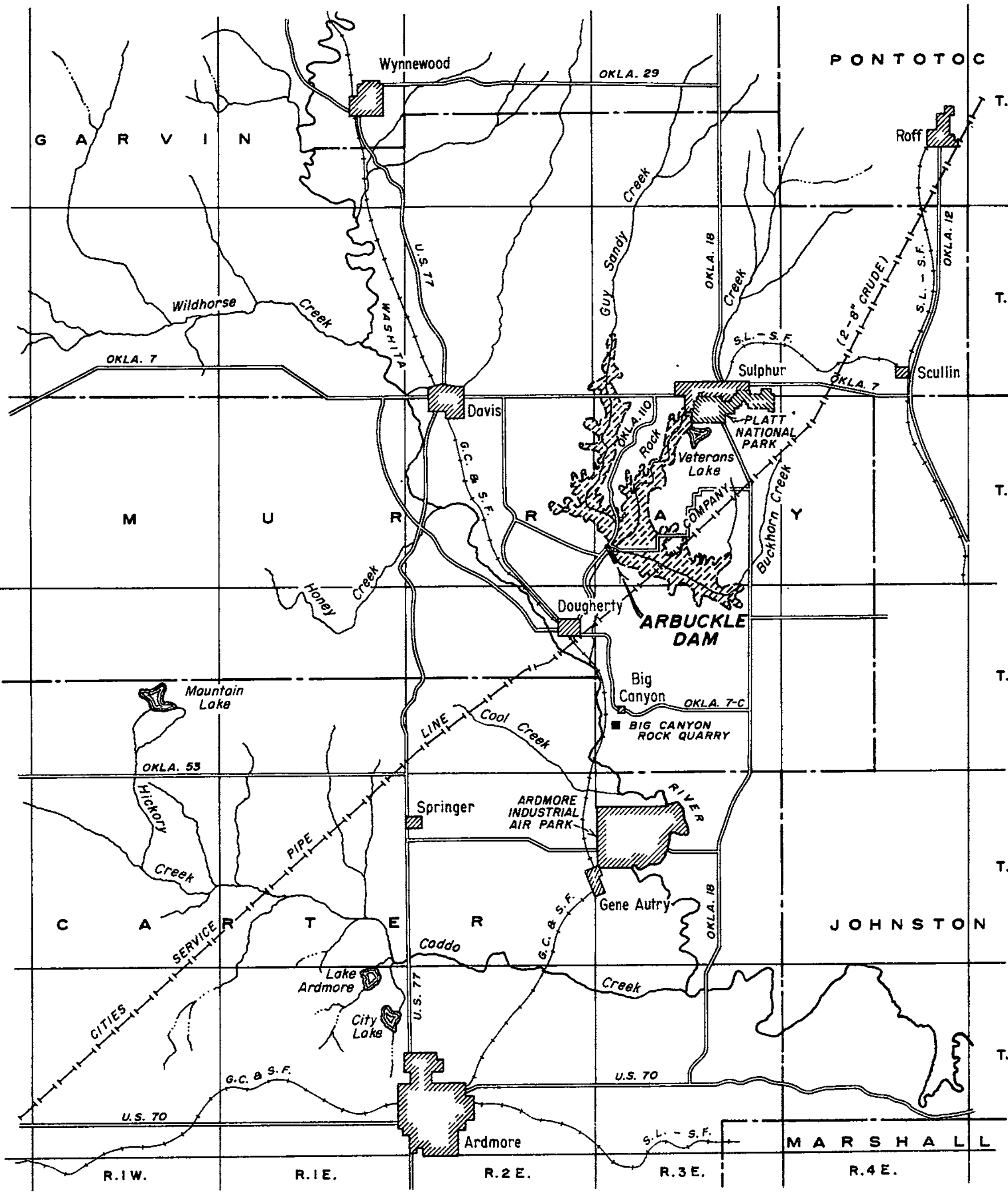
Q cfs	Tailwater elevation	Wave height (feet)
2,340	781.9	0.75
2,340	783.9	0.75
2,665	784.1	1.13
2,665	786.1	1.13

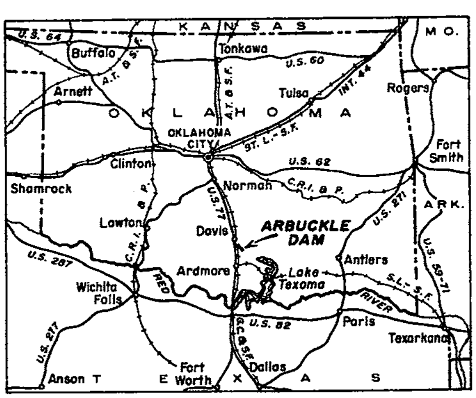
Table 3

TAILWATER SWEEPOUT TESTS

Q cfs	Minimum tailwater (degraded channel)	Initial sweepout*	Safety margin (feet)
2,340	781.9	778.9	3.0
2,665	784.1	781.4	2.7

*Tailwater elevation at which chute blocks initially become exposed.





KEY MAP

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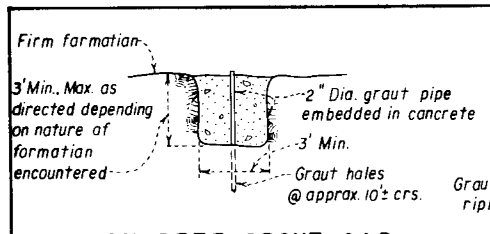
ARBUCKLE PROJECT-OKLAHOMA

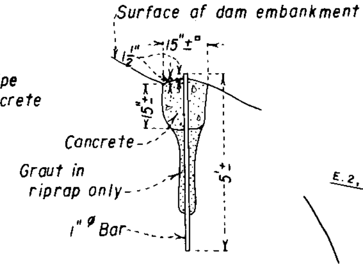
ARBUCKLE DAM
LOCATION MAP

DRAWN	H.W.C.	SUBMITTED	A. J. Larsen
TRACED	W.W.G.	RECOMMENDED	O. L. Rice
CHECKED	A.J.Lea	APPROVED	B. P. Bellport, CHIEF ENGINEER
DENVER, COLORADO	JUNE 20, 1963		882-D-2

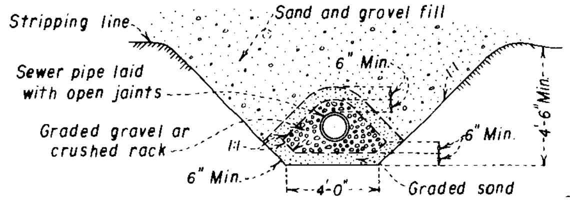
FIGURE 2
REPORT HYD-528



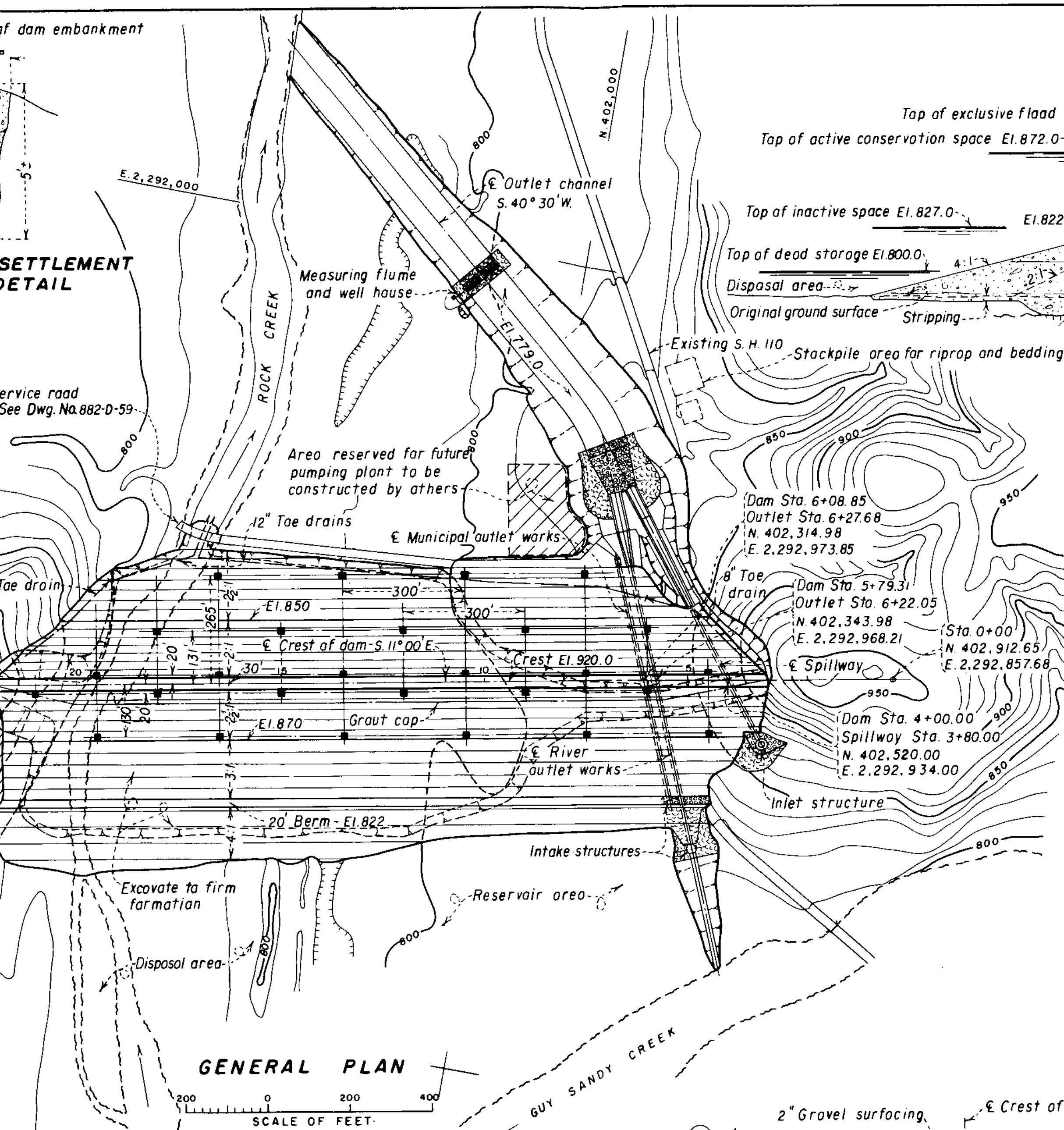
CONCRETE GROUT CAP



EMBANKMENT SETTLEMENT POINT DETAIL

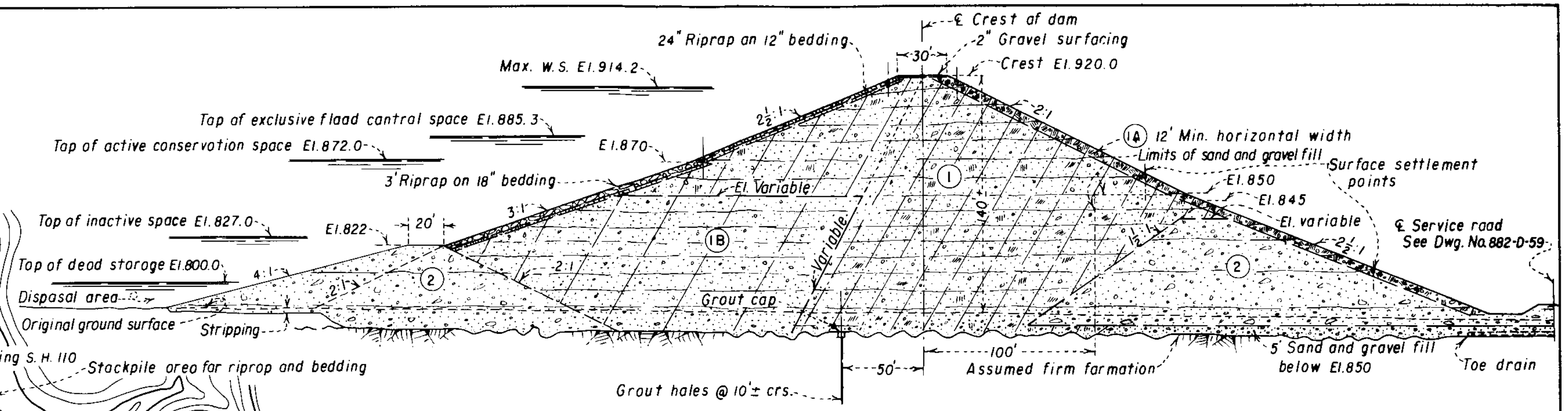


TOE DRAIN DETAILS



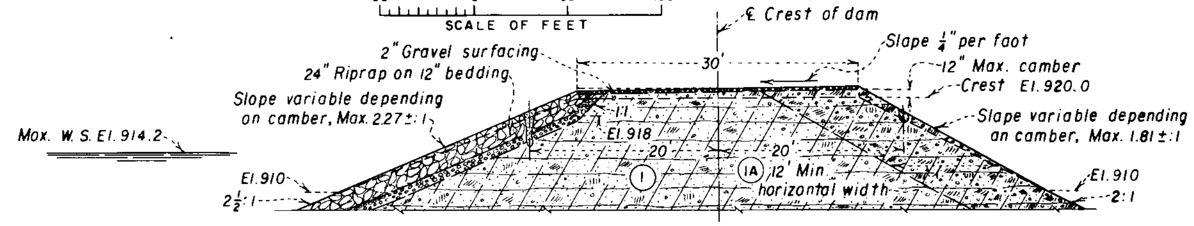
GENERAL PLAN

0 200 400
SCALE OF FEET



MAXIMUM SECTION

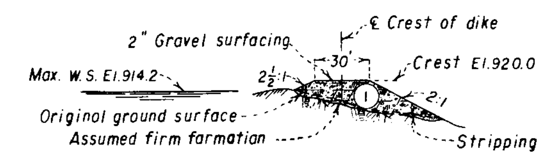
0 50 100
SCALE OF FEET



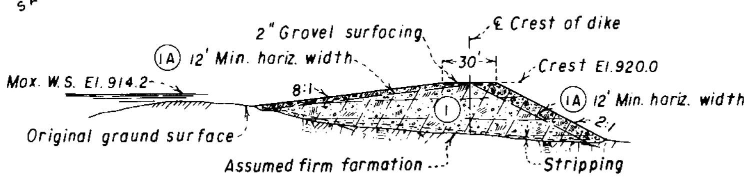
DETAILS OF CREST WITH MAXIMUM CAMBER

EMBANKMENT EXPLANATION

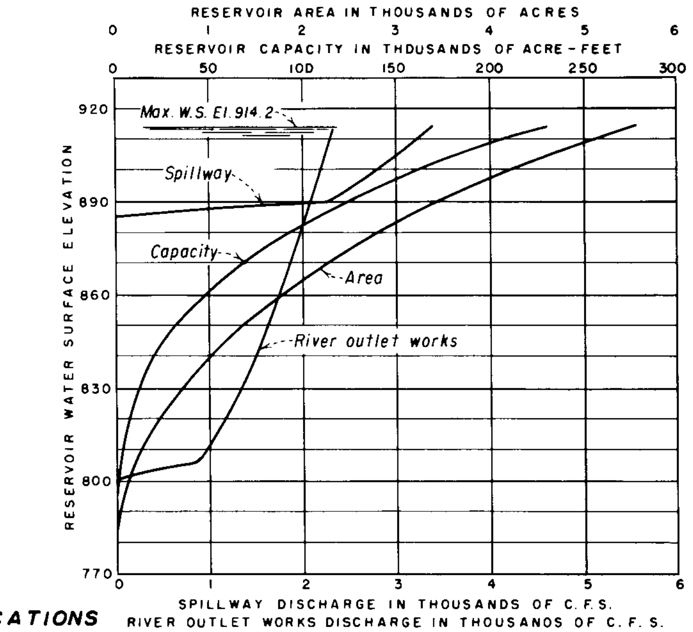
1. Selected clay, silt, and sand compacted by tamping rollers to 6-inch layers.
1A. Selected topsoil compacted by tamping rollers to 6-inch layers.
1B. Selected clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers.
2. Selected miscellaneous material compacted by tamping rollers to 12-inch layers.



DIKE NO. 2



DIKE NO. 1

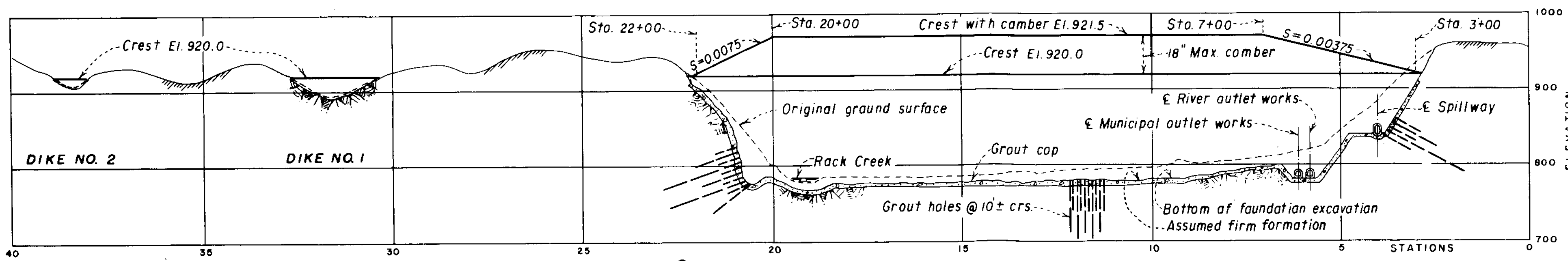


AREA - CAPACITY-DISCHARGE CURVES

RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATIONS	STORAGE ACRE-FEET
Flood control	872.0 to 885.3	36,440
Active conservation	827.0 to 872.0	62,571
Inactive	800.0 to 827.0	9,049
Dead	Streambed to 800.0	779
Total reservoir capacity		108,839 *

*Includes 7,500 a.f. allowance for 100 years sediment deposition between streambed and El. 872.0.
A surcharge of 123,185 a.f. (Max. W.S. El. 914.2) in combination with a spillway discharge of 3410 c.f.s. and a river outlet discharge of 2340 c.f.s. is provided to protect against the inflow design flood which has a peak of 168,500 c.f.s. and a 3-day volume of 138,300 a.f.



PROFILE ON € CREST OF DAM AND DIKES

ALWAYS THINK SAFETY

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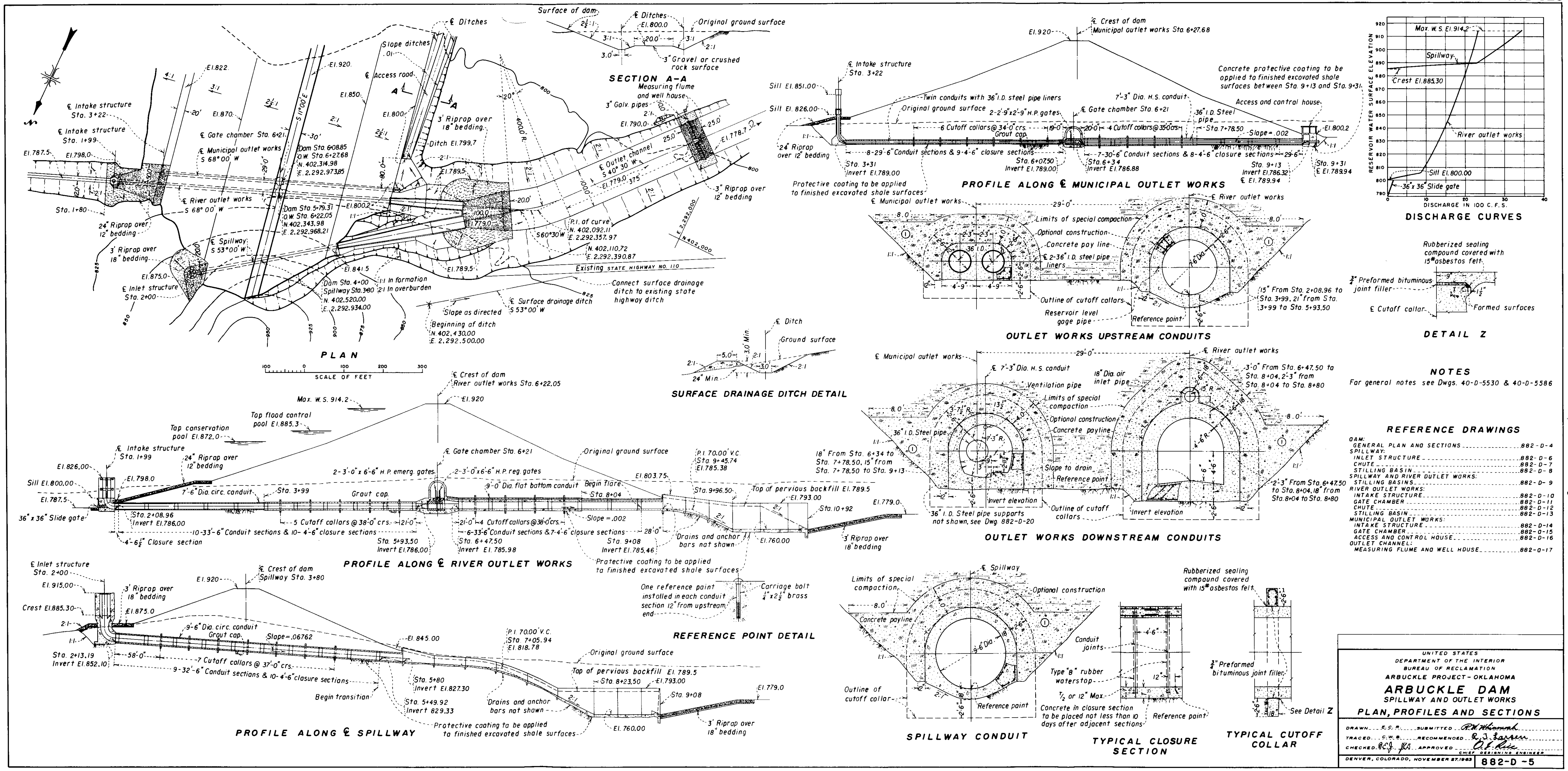
ARBUCKLE DAM
GENERAL PLAN AND SECTIONS

DRAWN H.W.C. SUBMITTED R. J. Larsen
TRACED C.W.B. RECOMMENDED O. L. Rice
CHECKED APPROVED B. P. Bellport, CHIEF ENGINEER

DENVER, COLORADO, NOVEMBER 27, 1963 882-D-4


PLAN
SCALE OF FEET
SECTION A-A
SURFACE DRAINAGE DITCH DETAIL
PROFILE ALONG ℄ RIVER OUTLET WORKS
PROFILE ALONG ℄ SPILLWAY
REFERENCE POINT DETAIL
PROFILE ALONG ℄ MUNICIPAL OUTLET WORKS
OUTLET WORKS UPSTREAM CONDUITS
OUTLET WORKS DOWNSTREAM CONDUITS
SPILLWAY CONDUIT
TYPICAL CLOSURE SECTION
TYPICAL CUTOFF COLLAR
DISCHARGE CURVES
RESERVOIR WATER SURFACE ELEVATION
DISCHARGE IN 100 C.F.S.
Max. W.S. El. 914.2
Spillway
Crest El. 885.30
River outlet works
Sill El. 800.00
36"x 36" Slide gate
DETAIL Z
Rubberized sealing compound covered with 15# asbestos felt
¾" Preformed bituminous joint filler
℄ Cutoff collar
Formed surfaces
NOTES
For general notes see Dwgs. 40-D-5530 & 40-D-5586
REFERENCE DRAWINGS
DAM:
GENERAL PLAN AND SECTIONS 882-D-4
SPILLWAY:
INLET STRUCTURE 882-D-6
CHUTE 882-D-7
STILLING BASIN 882-D-8
SPILLWAY AND RIVER OUTLET WORKS:
STILLING BASINS 882-D-9
RIVER OUTLET WORKS:
INTAKE STRUCTURE 882-D-10
GATE CHAMBER 882-D-11
CHUTE 882-D-12
STILLING BASIN 882-D-13
MUNICIPAL OUTLET WORKS:
INTAKE STRUCTURE 882-D-14
GATE CHAMBER 882-D-15
ACCESS AND CONTROL HOUSE 882-D-16
OUTLET CHANNEL:
MEASURING FLUME AND WELL HOUSE 882-D-17
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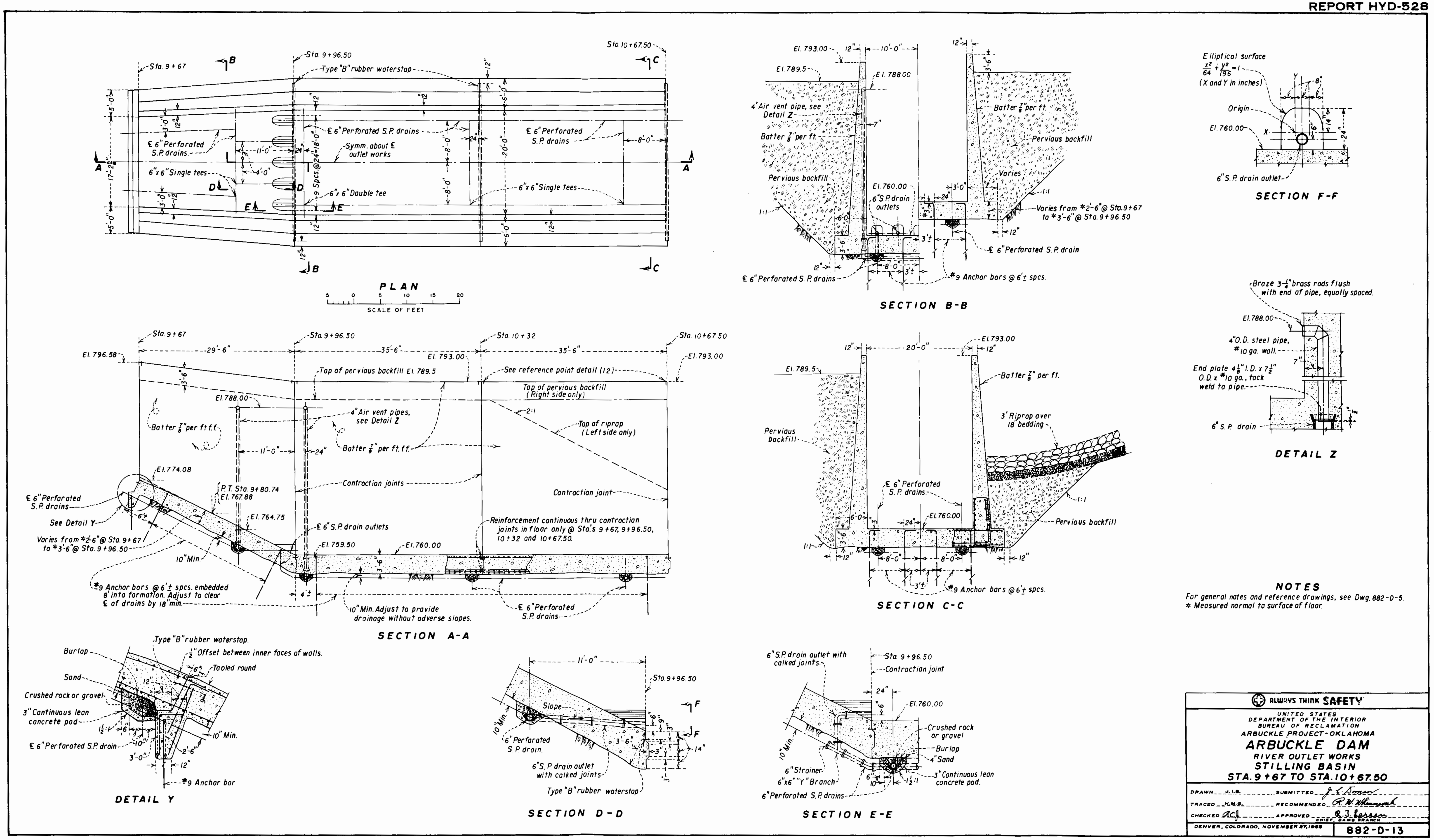
ARBUCKLE PROJECT - OKLAHOMA
ARBUCKLE DAM
SPILLWAY AND OUTLET WORKS
PLAN, PROFILES AND SECTIONS
DRAWN E.S.R. SUBMITTED
TRACED C.W.B. RECOMMENDED
CHECKED APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, NOVEMBER 27, 1963
882-D-5


PLAN
SCALE OF FEET
SECTION B-B
SECTION F-F
SECTION A-A
SECTION C-C
DETAIL Z
DETAIL Y
SECTION D-D
SECTION E-E
NOTES
For general notes and reference drawings, see Dwg. 882-D-5.
* Measured normal to surface of floor.
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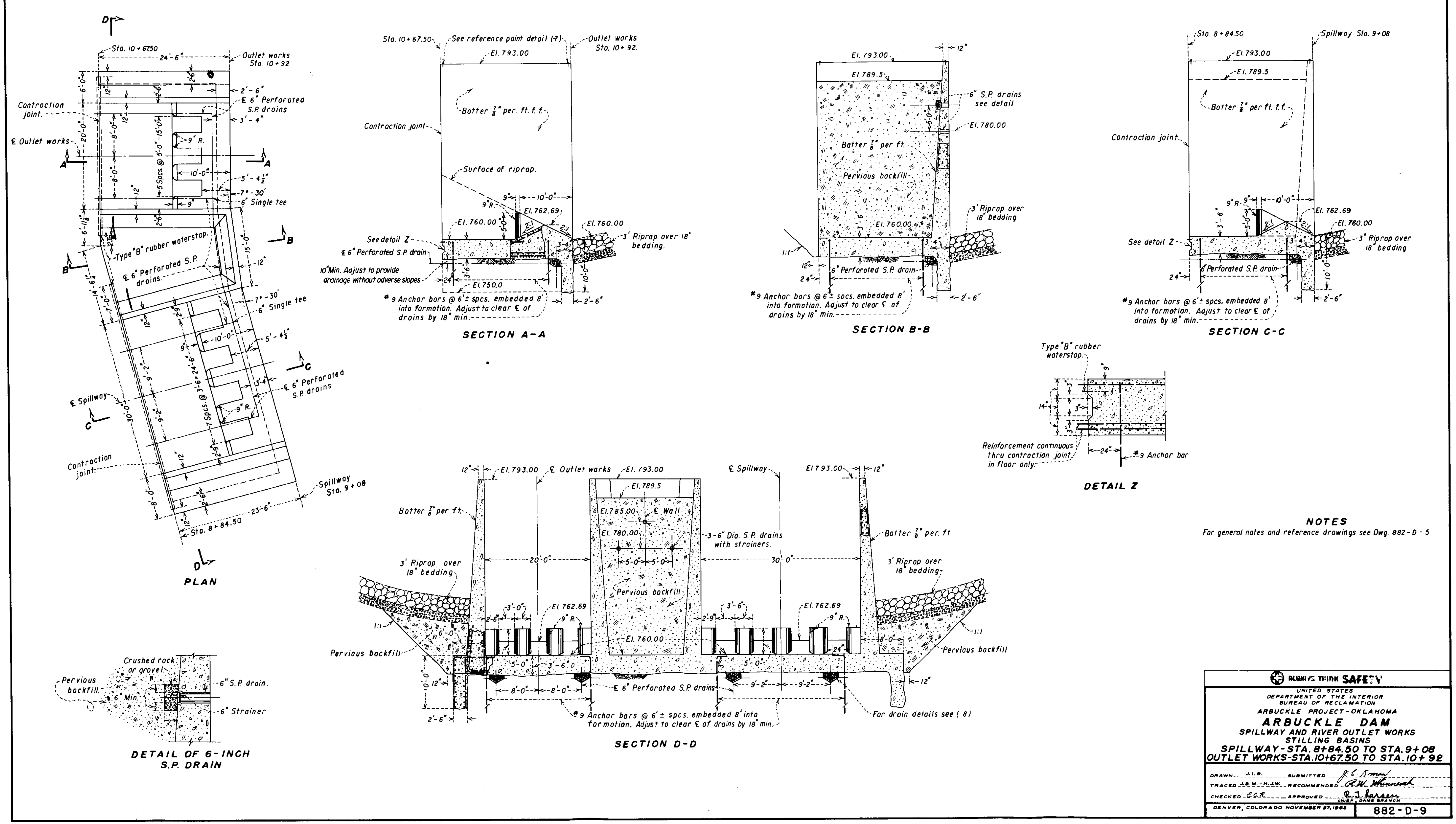
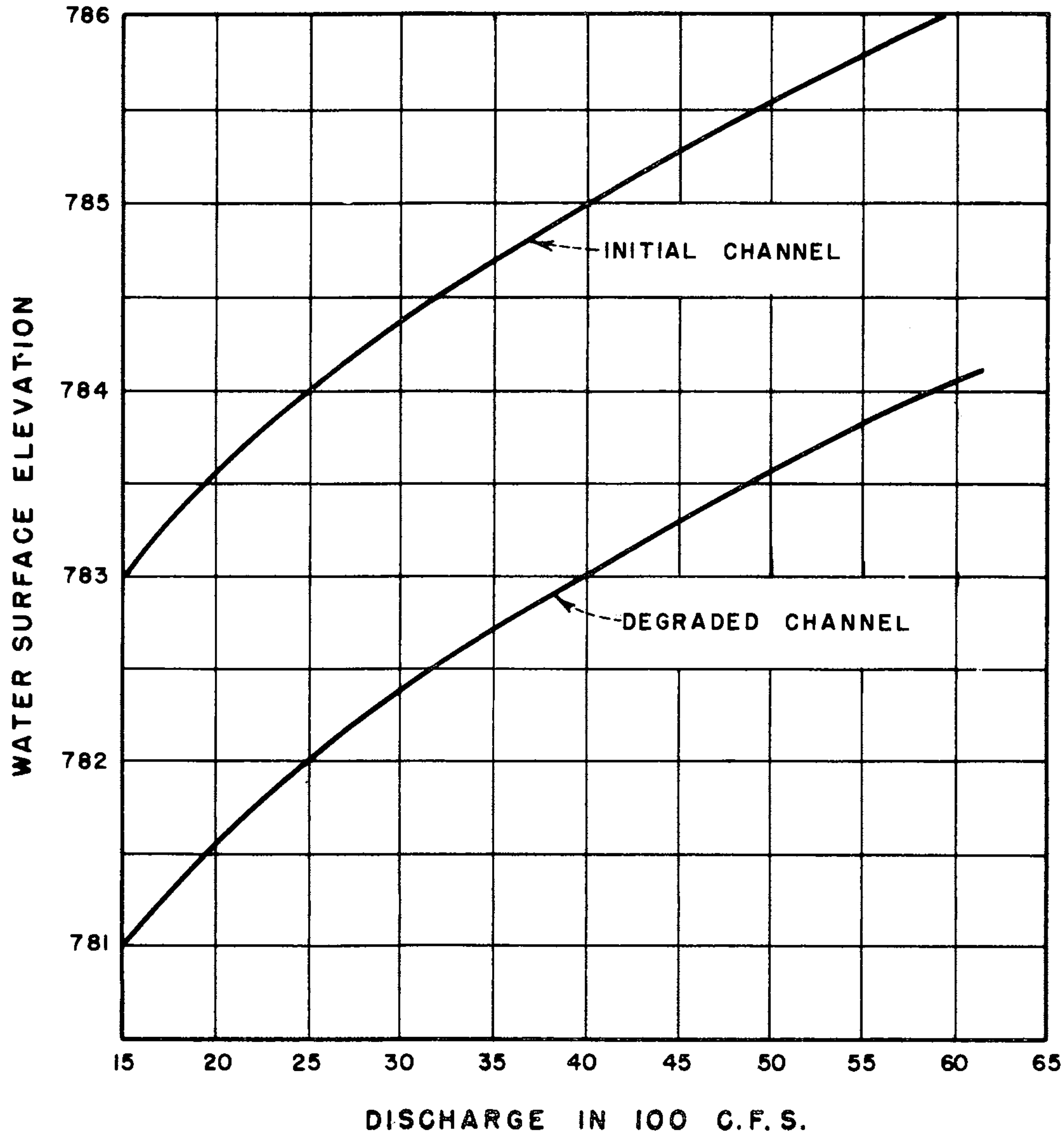
ARBUCKLE PROJECT-OKLAHOMA
ARBUCKLE DAM
RIVER OUTLET WORKS
STILLING BASIN
STA. 9+67 TO STA. 10+67.50
DENVER, COLORADO
882-D-13

FIGURE 4B
REPORT HYD-528





ARBUCKLE DAM
SPILLWAY AND OUTLET WORKS

TAILWATER CURVES

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model

Spillway stilling basin after operation of outlet works for 12 hours (prototype) at Q = 2, 340 cfs, tailwater elevation 781.9 (degraded channel). Note coarse material swept against end sill and fine material deposited in basin. No riprap protection in channel.

A. Tailwater elevation 781.9 (degraded channel)

B. Tailwater elevation 783.9 (initial channel)

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model

Stilling Basin operation and flow conditions in the downstream channel for outlet works Q = 2,340 cfs. Note upstream surge at end of spillway basin.

A. Tailwater elevation 784.1 (degraded channel)

B. Tailwater elevation 786.1 (initial channel)

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model

Stilling basin operation and flow conditions in the downstream channel for outlet works Q = 2,665 cfs.

A. Sand bed before erosion test

B. Q = 2,340 cfs, tailwater elevation 781.9
(degraded channel)

C. Erosion after equivalent of 12 prototype hours
operation at flow shown in B

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model
Erosion Test

A. Q = 2,665 cfs, tailwater elevation 784.1
(degraded channel)

B. Erosion after equivalent of 12 prototype hours
operation at flow shown in A

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model
Erosion Test

Figure 10
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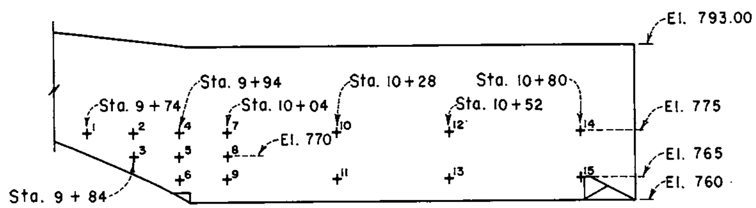
A. Riprap before test.

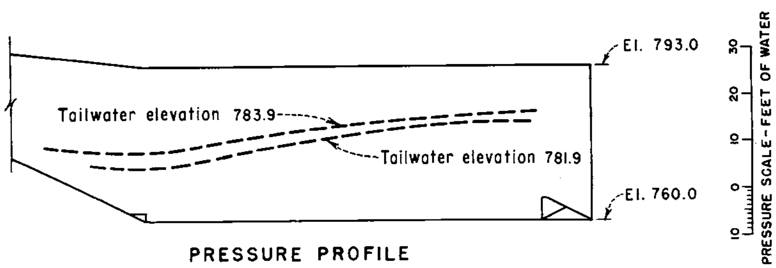
B. Riprap after equivalent of 12 prototype hours at Q = 2,665 cfs, tailwater elevation 784.1 (degraded channel)

ARBUCKLE DAM OUTLET WORKS
1:18 Scale Model
Riprap Test

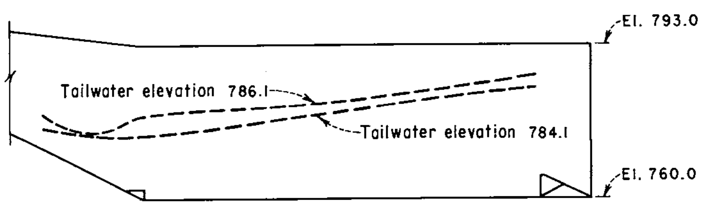


PIEZOMETER LOCATIONS
ELEVATION

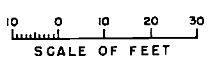
PIEZOMETERS ARE LOCATED IN RIGHT TRAINING WALL OF STILLING BASIN



PRESSURE PROFILE
Q = 2340 C.F.S.



PRESSURE PROFILE
Q = 2665 C.F.S.



PRESSURES - PROTOTYPE FEET OF WATER
Q = 2340 C.F.S.

PIEZOMETER NUMBER	TAILWATER ELEVATION 781.9						TAILWATER ELEVATION 783.9					
	WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
1	—	—	—				1.8	0.4	1.1			
2	—	—	—				1.4	0.2	0.8			
3	3.1	1.3	2.2	23.6	-9.7	1.4	6.3	4.3	5.3	55.1	-31.3	4.7
4	—	—	—				2.3	0.7	1.5			
5	3.1	1.6	2.4	19.3	-5.9	2.2	6.8	4.5	5.7	30.4	-17.6	6.7
6	7.2	5.9	6.6	39.6	-11.9	7.9	11.2	9.0	10.1	38.5	-15.8	11.5
7	—	—	—	7.4	-7.7	-0.5	2.2	0.5	1.4	17.1	-12.2	0.4
8	3.4	1.8	2.6	11.5	-4.3	0.2	6.5	4.7	5.6	17.3	-11.5	4.7
9	8.1	6.8	7.5	28.8	-10.3	5.9	12.1	9.5	10.8	29.3	-6.7	9.5
10	3.8	1.8	2.8				6.5	3.8	5.2			
11	12.4	10.4	11.4				15.7	13.3	14.5			
12	7.0	4.1	5.6				8.6	6.1	7.4			
13	16.2	13.7	15.0				17.8	15.8	16.8			
14	7.4	6.8	7.1				9.2	8.5	8.9			
15	17.1	16.2	16.7				18.9	18.2	18.6			

Q = 2665 C.F.S.

PIEZOMETER NUMBER	TAILWATER ELEVATION 784.1						TAILWATER ELEVATION 786.1					
	WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE			WATER MANOMETER PRESSURE			INSTANTANEOUS PRESSURE		
	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE
1	0.4	-0.2	0.1				4.1	1.6	2.9			
2	0.4	-0.2	0.1				3.4	1.8	2.6			
3	4.3	2.3	3.3	28.1	-11.2	4.7	5.0	3.1	4.1	39.6	-18.4	8.3
4	0.5	0.2	0.4				3.8	2.2	3.0			
5	4.5	2.7	3.6	22.0	-5.9	6.7	9.2	6.3	7.8	37.3	-5.9	10.3
6	9.2	7.2	8.2	33.1	-6.5	9.7	13.3	11.3	12.3	38.9	-5.2	13.3
7	0.5	0.2	0.4	18.4	-13.1	0.4	3.6	1.8	2.7	19.3	-12.4	3.1
8	4.5	2.7	3.6	14.6	-6.5	4.7	8.8	6.5	7.7	20.5	-9.0	6.5
9	10.3	8.1	9.2	27.0	-1.6	9.5	15.5	11.7	13.6	39.8	-6.3	13.1
10	4.5	2.2	3.4				7.0	4.9	6.0			
11	13.5	11.2	12.3				16.0	13.9	15.0			
12	7.4	5.6	6.5				9.2	7.2	8.2			
13	16.7	14.2	15.5				18.4	16.0	17.2			
14	9.4	8.6	9.0				11.2	9.9	10.6			
15	19.4	18.5	19.0				22.0	20.3	21.2			

Pressure measured above piezometer opening.
Blank spaces indicate no data were taken.

NOTE

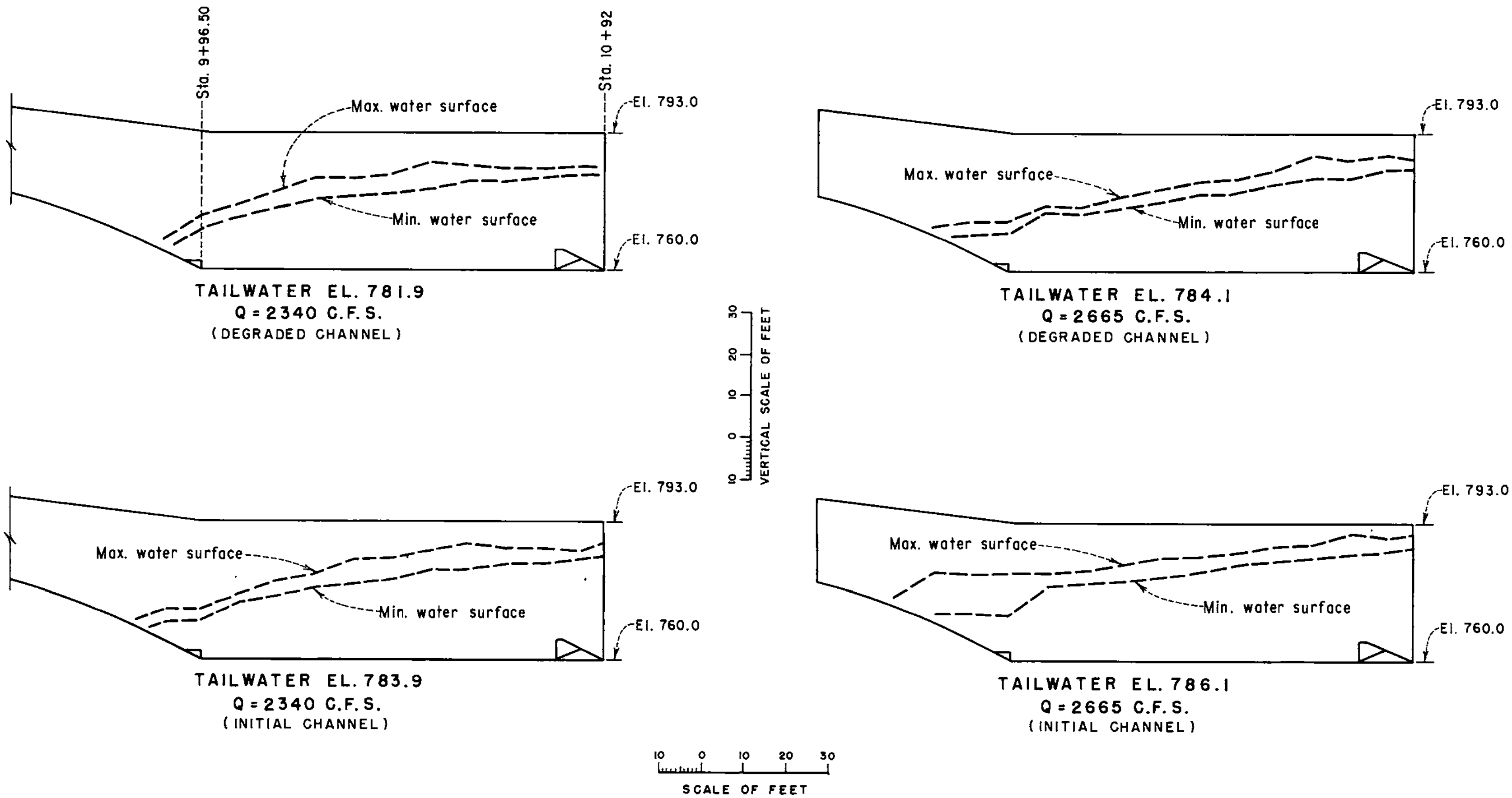
Pressure profiles are based on average water manometer pressures at piezometer numbers 1, 3, 6, 9, 11, 13, and 15.

ARBUCKLE DAM OUTLET WORKS

1:18 SCALE MODEL

PIEZOMETER LOCATIONS, STILLING BASIN PRESSURES, AND PRESSURE PROFILES

FIGURE 11
REPORT HYD-528



ARBUCKLE DAM OUTLET WORKS

1:18 SCALE MODEL

STILLING BASIN WATER SURFACE PROFILES

HYD-528
King, D. L.
HYDRAULIC MODEL STUDIES OF ARBUCKLE DAM OUTLET WORKS, ARBUCKLE PROJECT, OKLAHOMA
Laboratory Report, Bureau of Reclamation, Denver, 12 p, 3 tables, 12 figures, 1 reference, 1964

DESCRIPTORS--*outlet works/*model tests/*stilling basins/ hydraulic jumps/hydraulics/hydraulic structures/scour/riprap/ eddies/wave action/water pressures/piezometers/pressure measuring equipment/recording systems/water surface profiles/ hydraulic models/ spillways/ backwater/ erosion/ negative pressures/ hydrostatic pressures/ discharge measurement/ freeboard/ safety factors/ operations

IDENTIFIERS--Arbuckle Project, Oklahoma/ Arbuckle Dam

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IDENTIFIERS--Arbuckle Project, Oklahoma/ Arbuckle Dam

ABSTRACT

Studies of a 1:18 scale model were made primarily to determine possible effects of operation of the outlet works on flow conditions in the downstream channel when the neighboring spillway is not operating. Also, operating characteristics of the outlet works stilling basin were observed and recorded. Conclusions of the study were: (1) Operation of the outlet works had no serious effects on flow conditions in the downstream channel. (2) The outlet works stilling basin performed satisfactorily for the test discharges. (3) Erosion in the simulated channel was moderate and the model indicated that the prototype riprap would give adequate protection against scour. (4) Pressures along the walls of the stilling basin were within safe limits of operation. (5) Water surface profiles indicated adequate freeboard against overtopping of the basin walls. (6) Waves in the downstream channel were 1 foot or less in height. (7) For the maximum outlet works discharge a safety margin of 2.7 feet was measured between the tailwater elevation with degraded channel and the tailwater elevation at which the hydraulic jump moves downstream and initially exposes the chute blocks.

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